Regional Differences in Feto-Infant Mortality in the U.S. - Mexico Border Region: Using the Perinatal Period of Risk (PPOR) Approach

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REGIONAL DIFFERENCES IN FETO-INFANT MORTALITY IN THE U.S.-MEXICO BORDER REGION: USING THE PERINATAL PERIODS OF RISK (PPOR) APPROACH

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Dedication

To the memory of my father, that as young as I can remember instilled in me to reach for the stars...
REGIONAL DIFFERENCES IN FETO-INFANT MORTALITY IN THE U.S.-MEXICO BORDER REGION: USING THE PERINATAL PERIODS OF RISK (PPOR) APPROACH

by

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DISSERTATION

Presented to the Faculty of the Graduate School of
The University of Texas at El Paso
in Partial Fulfillment
of the Requirements
for the Degree of

DOCTOR OF PHILOSOPHY

Department of Interdisciplinary Health Sciences, PhD Program
THE UNIVERSITY OF TEXAS AT EL PASO
December 2018
Acknowledgements

I would like to express my deepest appreciation and gratitude to my advisor, Dr. Christina Sobin, for her mentorship, understanding, and all the guidance throughout my doctoral work. Also, I would like to thank my committee members, Dr. Jill McDonald, Dr. Carla Campbell, and Dr. Maria Duarte for the guidance and thought-provoking suggestions through the completion of my degree. I am fortunate to have had passionate researchers as members in my doctoral committee that have contributed to my intellectual growth and have inspired me to continue learning.

I would also like to thank all the individuals throughout my career in public health that mentored me to grow professionally and encouraged me to continue with my education, especially Dr. Roger Fillingim, Dr. Jill McDonald, Dr. Khaleel Hussaini, Mary Ellen Cunningham, and Dr. Christiane Herber-Valdez.

Lastly, I would like to acknowledge the innumerable sacrifices made by my husband, Omar, in taking up most of the household chores the last four years and understanding when I was swamped with assignments and had to dedicate so many weekends and evenings to school work. Also, for encouraging me in the moments when I thought it was too hard to complete this degree.
Abstract

Introduction. Infant mortality (IM) is a critical indicator of the health of communities because societal factors that affect population health directly impact the mortality rate of infants. There is limited infant mortality data for the U.S. side of the U.S.-Mexico Border Region, defined as the areas within 100 km north of the border. Data from 2005-2007 show that the average IM rate for the border states combined was 5.8 infant deaths per 1,000 live births; for the border counties the rate was 5.4 per 1,000. Although IM rates were lower in the border counties than in the border states, risk factors that predict IM were significantly higher in the border region. For example, from 2006-2008 preterm births were higher among Hispanics than non-Hispanic whites in the border counties (12.9% vs. 10.4%); in the border states overall (12.0% vs. 11.2%); and in the U.S. (12.2% vs. 11.4). Also, rates of low birthweight infants were higher among Hispanics than non-Hispanic whites in the border counties (7.3% vs. 6.6%). Models that simultaneously characterize IM while suggesting prevention approaches can be valuable. For example, the Perinatal Periods of Risk (PPOR) model provides an analytic framework for calculating excess fetal and infant mortalities while identifying highest risk periods of infant care for specified subgroups. The model divides fetal and infant deaths into four chronological Perinatal Periods of Risk according to infant birth weight and age at death. Using this approach in the border region could help to identify periods of elevated risk which in turn would indicate specific types of needed interventions. The goals of this study were to test differences in: 1.) overall feto-infant mortality rate for the U.S. border counties in the four border states and a.) non-border counties in the four border states; b.) all counties in the border states; and c.) the U.S. national rates; 2.) excess feto-infant deaths in border counties and non-border counties in the four border states; 3.) specific periods of risk in which excess feto-infant deaths occur in border counties and non-border counties in the U.S. border states; 4.) specific risk factors associated with low birthweight and prematurity in the U.S. Mexico border region; 5.) maternal characteristics associated with an infant dying in the U.S. border states; and 6.) factors
associated with the leading cause of death in the PPOR with the highest excess deaths in the U.S Mexico border region. **Methods.** This was a retrospective cohort study of 25,000 infant deaths occurring before the age of one year in the four border states of Arizona, California, New Mexico, and Texas from 2009-2013. Linked birth-death and fetal death datasets from the National Center for Health Statistics (NCHS) were used. The PPOR approach for fetal and infant mortality was used to first characterize all deaths by age at death (fetal, neonatal, post-neonatal) and birth weight (500-1499, 1500g or more) and then use this information to categorize deaths into one of four maternal/infant care time periods (as defined by the PPOR model) including Maternal Health/Prematurity (MHP), Maternal Care (MC), Newborn Care (NC), and Infant Health (IH). Mortality rates were calculated for each period to estimate the overall IM rate, and then compared to a standard reference group, consisting of deliveries to White-non-Hispanic women, 20 years of age and older, residing in California to determine the preventable (excess) deaths. National infant death rates were calculated from the NCHS files and compared with NCHS yearly published rates. Chi-square tests were used to test whether specific factors increased the likelihood ratios of low birthweight, prematurity, and infant death. Also, multivariate logistic regression models were used to test which risk factors were associated with the leading cause of death in the PPOR with the highest excess deaths in the border counties overall. **Results.** The overall fetal-infant death rate in the border counties was 6.3 fetal-infant deaths per 1,000 live births and fetal deaths, from 2009 to 2013. This rate was lower than the national average (7.8 per 1,000), border states average (6.9 per 1,000), and the non-border counties average (7.0 per 1,000). The excess fetal-infant mortality rate of the border counties in the four border states was 0.8 fetal-infant deaths per 1,000 live births and fetal deaths, which equates to 460 preventable deaths. In the border counties, the highest excess death rate was found in the Maternal Health/Prematurity (MHP) perinatal period (0.4 per 1,000), similar to the non-border counties (MHP= 0.7 per 1,000). However, the MHP in the border counties contributed 52% to the overall excess death and the pathway associated with feto-infant death was birthweight distribution (babies born with very low birthweight (VLBW)); while VLBW
babies contributed the most to the feto-infant death rate for the border counties. In the border counties smoking (AOR= 1.4; 95% CL: 1.2-1.7), and previous pre-term birth (AOR= 3.0; 95% CL: 2.5-3.5) were associated with having a VLBW baby. Border mothers that experienced infant death were in fact less likely to have a medical risk and to smoke during pregnancy, and more likely to be married, have no or late prenatal care and have >13 years of education as compared to mothers that experienced an infant death in a non-border state. **Impact.** The traditional IM indicator cannot provide an indication of causal factors. PPOR analyses however go beyond traditional IM indicators and provide a well-tested and systematic approach for determining in which chronological periods of risk excess infant deaths are occurring for a particular region. This in turn can guide community-based inventions with the highest likelihood of reducing infant deaths. Using this approach, these findings provide strong evidence that intervention to reduce infant deaths in border counties should focus on the MHP (maternal health/prematurity) period of risk. Moreover, this study substantially adds to the current body of knowledge regarding excess deaths and infant mortality in the U.S.-Mexico border region.
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Chapter 1: Introduction and Background

1.1 U.S. - Mexico Border Region

The U.S.-Mexico Border Region is known as a geographic area with strong social, cultural, environmental, and economic interconnections that are governed by different policies and laws from the two neighboring countries (Lee et al., 2013). The area is bicultural (composed of Mexican and American cultures) with a large portion of the population crossing back and forth daily for work, school, tourism, and healthcare, among other reasons (U.S.- Mexico Border Health Commission, 2014b). For instance, in 2016 alone there were 42.2 million pedestrian crossings and 143 million passenger car and bus crossings at the 24 official ports of entry (Bureau of Transportation Statistics, 2017). Also, in 2009, 196,000 Mexican-born immigrants traveled temporarily and legally to the U.S to work, and about 86,000 to study (Centers for Disease Control and Prevention, 2013). The economy of the border is dependent on the open crossing between the countries. Many new businesses are created by Mexican entrepreneurs on the U.S. side of the border, creating a demand for goods and services and increased of border crossing for retail and tourism in many of the border U.S. cities (Lee et al., 2013). Even nationally, Mexico is the top country of origin for international travelers to the U.S. (19%) and top travel destination for U.S. residents (32%) (Centers for Disease Control and Prevention, 2013). When it comes to trade, the U.S. is Mexico's top trading partner, and Mexico is the U.S largest third trading partner and second export market (Lee et al., 2013; U.S.- Mexico Border Health Commission, 2014b; United States-Mexico Border Health Commission, n.d.). For instance, in 2010 the U.S.-Mexico trade crossing the border was about 225 billion dollars, and 70% of bilateral trade crosses the border in trucks (Lee et al., 2013), demonstrating a significant amount of business that crosses the border.

The high volume of border crossings and trade has forced local collaboration between both countries when it comes to public health, security, trade, border management and environmental resources (Lee et al., 2013). For instance, for governance, many organizations
have formed to facilitate communication between the countries. These groups included the U.S.-
Mexico Border Health Commission, Border Environmental Cooperation Commission, Border
Governor Conference, U.S.-Mexico Border Mayor Association, and the U.S.-Mexico Border
Philanthropy Partnerships (Lee et al., 2013). Also, groups to address bi-national health issues
and for infectious diseases surveillance have been formed in the U.S.-Mexico border region by
the CDC and essential local border partners. These programs and groups include the U.S.-
Mexico Binational Technical Working Group, the Binational Border Infectious Disease
Surveillance Program, and the Migrant Health Program (Centers for Disease Control and
Prevention, 2017).

With regard to health issues, the border region poses some challenges because diseases
and determinants of health affect both sides, due to the area being highly integrated and having
such a mobile population. This population fluidity has also forced collaboration in the public
health sector, where public health professionals in the county and states from both countries
work together to solve health problems affecting both sides. One example is the work of the
U.S.-Mexico Binational Technical Working Group, and the U.S.-Mexico Border Health
Commission, which evaluated the health status of the border region to developed binational
health indicator targets for 2010 and 2020, including the Healthy Border publications, similar to
U.S. Healthy People indicators (Office of Disease Prevention and Health Promotion, 2014; U.S.-

Thus, the border is a unique region unlike any other region in the U.S. with its distinctive
binational social, cultural, and economic relationships, yet at the same time remaining sovereign
states and counties with U.S. laws and regulation. Due to the interconnection, health issues and
diseases do not stop at one side of the border making the international border line blurred and
requiring that health challenges to be addressed binational.
1.1.1 Definition of the border

The La Paz agreement defined the region as 100 kilometers north and south of the international borderline between the U.S. and Mexico. It extends 3,141 km (2,000 miles) from the Gulf of Mexico to the Pacific Oceans (Mumme & Collins, 2014; Pan American Health Organization, 2012a). This agreement was signed by both countries to protect and improve the environment along the international border (Pan American Health Organization, 2012a). The U.S.-Mexico Border Health Commission further defined the region to include along the international borderline 44 counties in four states (Arizona, California, New Mexico, and Texas) on the U.S. side and 80 municipios in six states (Chihuahua, Coahuila, Nuevo Leon, Tamaulipas, Sonora, and Baja California) on the Mexican side, including 15 pairs of sister cities (Pan American Health Organization, 2012a; U.S.-Mexico Border Health Commission, 2003). This definition aimed to facilitate managing programs along the border to improve health conditions (Lee et al., 2013; Pan American Health Organization, 2012a).

1.1.2 Population on the U.S.-Mexico Border Region

As of 2010, approximately 15 million people live in the U.S.-Mexico border region, equally divided on both sides (Lee et al., 2013; Pan American Health Organization, 2012a; U.S.-Mexico Border Health Commission, 2003). On the U.S. side, about 70 million people live in the four border states and represent 23% of the total U.S. population (U.S.-Mexico Border Health Commission, 2014b). The population is young, with 24% being under 15 years of age (Pan American Health Organization, 2012a). Moreover, approximately, 300,000 births occur annually in this region (McDonald, Mojarro, Sutton, & Ventura, 2013) and is increasing with high fertility rates and continuous migratory flow in the area. In the last decade (from 2000 to 2010), the Mexican border population increased 18% while the border population on the U.S. side increased 12% (Pan American Health Organization, 2012a). The population is expected to reach 29 million inhabitants by 2045, resulting in 5% of the combined population of both nations (Lee et al., 2013; Pan American Health Organization, 2012a).
1.1.3 Disparities and health in the U.S.-Mexico Border Region

Although the border is recognized as one region, there are vast differences that exist between the two countries. A more substantial proportion of Hispanic inhabitants of the U.S. border region live below the federal poverty level compared to the rest of the U.S. (Health Resources and Services Administration, 2009; U.S.-Mexico Border Health Commission, 2014a), and women are significantly more likely to be living in poverty than men (Health Resources and Services Administration, 2009). Likewise, 37% of children (under 18 years old) living on the border (except for San Diego County, California) live in poverty compared to 20% nationally (U.S.-Mexico Border Health Commission, 2014a). United States border residents also have lower levels of education than the national average (U.S.-Mexico Border Health Commission, 2003) and they are also less likely to have health insurance (Health Resources and Services Administration, 2009; Pan American Health Organization, 2012a). In 2013, the four border states had the highest rates on uninsured (Texas=27%, New Mexico= 24, California= 21%, and Arizona=20%) compared to the U.S. rate of 18% (U.S. - Mexico Border Health Commission, 2014a).

Higher incidence of health and reproductive problems exist on the border (McDonald et al., 2008; McDonald et al., 2013; Xaverius, Salas, Kiel, & Woolfolk, 2014). When it comes to birth outcomes, such as infant deaths and stillbirths in the border counties, the data are limited. Some of the literature suggests that risk factors such as late or no prenatal care, low birthweight, and prematurity account for these adverse birth outcomes. Late or no prenatal care is more prevalent in the border regions than in the non-border areas in U.S. border states (McDonald et al., 2008; McDonald et al., 2013). Also, low birth weight and prematurity are more prevalent in the U.S. border counties (McDonald et al., 2013).

1.2 The Importance of Infant Mortality

Infant mortality refers to infants that die during the first year of life (Centers for Disease Control and Prevention, 2017). It is often used as an indicator to measure the health and well-
being of a community or nation because societal factors that affect population health directly impact the mortality rate of infants (Crump, Sundquist, Sundquist, & Winkleby, 2011; Peck, Sappenfield, & Skala, 2010; Sappenfield, Peck, Gilbert, Haynatzka, & Bryant III, 2010a). It is related to socioeconomic and behavioral characteristics, environmental and biomedical factors, genetics, quality and access to health services, among other factors (Association of Maternal and Child Health Programs, 2013; Crump et al., 2011; Peck et al., 2010). Studying infant mortality can identify the overall health in a community. The same factors that affect pregnancy outcomes, such as chronic diseases, barriers to health care, behavioral risks (e.g., smoking) also affect the overall health of populations (Sappenfield et al., 2010a).

Also, IMR is one of the leading health indicators for Healthy People 2020, which are subsets of objectives selected to communicate high priority issues (Hirai et al., 2014; Office of Disease Prevention and Health Promotion, 2014). The target was to reduce all fetal and infant mortality to 6.0 deaths per 1,000 live births by 2020, which is a 10% reduction from the 2006 baseline of 6.7 deaths per 1,000 live births (Office of Disease Prevention and Health Promotion, 2014). Similarly, Healthy Border 2010 and 2020 program created objectives for disease prevention and health promotion aimed to improve health in the U.S. – Mexico Border region. The Healthy border 2010 objectives were to reduce infant mortality rate by 15% from the 2001 baseline of 5.4 per 1,000 live births to a target of 4.6 per 1,000 and infant mortality due to birth defects by 30% from the 2000 baseline of 1.5 to a target of 1.1 on the U.S. side (U.S.-Mexico Border Health Commission, 2003). Although maternal and child health was one of the five health priority topics identified by the Border Health Research Panel tasked with the development of the 2020 Healthy border objectives, infant mortality was not an objective chosen for Healthy Border 2020 (U.S.-Mexico Border Health Commission, 2014b)). The panel thought that differences in IMR would be difficult to compare between national, state and border rates due to lack of a centralized surveillance system and data only available at the state level (U.S. - Mexico Border Health Commission, 2014b). However, objectives associated with birth
outcomes were included such as increasing access to prenatal care, prenatal vitamins and supplements, awareness of healthcare in early pregnancy and healthy behaviors among women.

1.2.1 The infant mortality rate

The infant mortality rate (IMR) refers to the number of infant deaths for every 1,000 live births (Association of Maternal and Child Health Programs, 2013; Barfield et al., 2013; Centers for Disease Control and Prevention, 2017; Sappenfield et al., 2010a). The rate is intended to show the probability that an infant with specific characteristics will die between birth and one year of age (Barfield et al., 2013; Peck et al., 2010; Sappenfield et al., 2010a).

There are several ways to calculate the IMR. The traditional IMR is calculated by dividing the number of infant deaths in a year by the number of live births in the same year (Association of Maternal and Child Health Programs, 2013; Barfield et al., 2013; Centers for Disease Control and Prevention, 2017; Sappenfield et al., 2010a). A more accurate way to calculate infant mortality risk is to calculate the rate by a birth cohort or a period. With the birth cohort, infant mortality is calculated by dividing the number of infant deaths in a given year’s birth cohort (numerator) by all the live births occurring the same year (Sappenfield et al., 2010a). For instance, if we look at the year 2013, the numerator would be all infant deaths that happened in the 2013 birth cohort, even if the death occurred in 2014. The denominator would be all births in 2013. In contrast, the period infant mortality is calculated by dividing all infant deaths in a given year (the numerator) by all births occurring that same year (Sappenfield et al., 2010a). For instance, for 2013, the numerator would be all infant deaths in 2013, even if the birth occurred in 2012 and the denominator would be all births in 2013. This latter method approximates the traditional IMR and is useful when it is not practical to wait for an additional year to have a complete birth cohort. The period method can introduce some bias if substantial changes occur in the population, the healthcare system, or the infant mortality rate over a short period when comparing multiple years. This is because the shifts seen may be attributed to these factors opposed to changes in health risks (Peck et al., 2010; Sappenfield et al., 2010a).
Another method is to calculate excess deaths, which is an often-used epidemiological index in chronic diseases to determine untimely deaths in a population. Excess mortality refers to deaths above what would be expected based on a baseline rate (Checchi & Roberts, 2008). It is estimated by taking the difference between the number of deaths observed in a population or subgroup (e.g., Hispanic mothers) and the number of deaths that would have occurred in that group if it had the same death rate as of another population or subgroup (e.g., white mothers) (Centers for Disease Control and Prevention, 2000; Checchi & Roberts, 2008).

Using a feto-infant mortality rate, which includes fetal and infant deaths can be helpful to get a complete picture of the risk factors affecting infant mortality since the same risks that affect infant deaths also affect fetal deaths (Sappenfield et al., 2010a). For instance, factors like chronic diseases, health behaviors, and prenatal care jeopardize both infant deaths and fetal deaths. The inclusion of fetal death data is advantageous because traditional infant mortality calculations do not consider in utero deaths when providing the rate of population-specific infant mortality. Therefore, traditional IMRs are limited in understanding infant deaths only or for developing approaches to reduce the risk of an infant dying (Gordis, 2014).

1.2.2 Current statistics on infant mortality

1.2.2.1 National rates

In 2013 there were approximately 3,932,181 million births in the U.S. and 23,466 infant deaths (Mathews, MacDorman, & Thoma, 2015). The infant mortality rate decreased to 6.0 infant deaths per 1,000 live births from the 2006 Healthy People 2020 baseline rate of 6.7 per 1,000, which is an 11% decrease (Mathews et al., 2015; Office of Disease Prevention and Health Promotion, 2014). In, 2013 the IMR reached the Healthy People 2020 target of 6.0 deaths per 1,000 live births. The same trend is seen among all ethnic groups. Among Hispanics, the rate declined 11% from 5.6 to 5.0 deaths per 1,000 live births, and among Mexican mothers, it decreased 9% from 5.4 to 4.9 deaths per 1,000 live births from 2005-2007 to 2012-2014 (Matthews & Driscoll, 2017).
In the U.S. the race and ethnic group with the best outcomes, thus the lowest IMR rate, are Asian or Pacific Islander mothers who had an infant mortality rate of 4.1 infant deaths per 1,000 live births in 2013. The groups with the highest rates were American Indian or Alaska Native mothers with nearly two times higher rate (7.6 per 1,000 live births) and black non-Hispanic mothers with 2.5 times higher rates (11.1 per 1,000 live births) than Asian/Pacific Islander mothers (Table 1) (Matthews & Driscoll, 2017).

Interestingly, Non-Hispanic white and Hispanic mothers had similar IMR of 5.1 and 5.0 per 1,000 live births, respectively (Table 1 and 2). Among Hispanic mothers, Puerto Rican mothers had the highest rates among Hispanic mothers with an IMR of 8.9 deaths per 1,000 live births, followed by Mexican Hispanic mothers with the second highest IMR of 4.9 per 1,000 live births (Mathews et al., 2015) (Table 2). Therefore, among Hispanics mothers, Puerto Rican and Mexican mothers have more infant deaths than other Hispanic mothers.

IMR differs by the age of the mother, those between 30-34 years old had the lowest rates, 4.9 infant deaths per 1,000 live births in 2013 (Table 2). The age groups with the highest IMR were to mothers under 20 years of age (8.5 per 1,000 live births) and mothers between 40-54 years old (7.8 per 1,000 live births) (Mathews et al., 2015). Thus, showing that younger and older mothers had higher infant mortality rates. The same pattern is seen among all Hispanic mothers. Mexican Hispanic mothers aged 25-29 years had the lowest rate but also had mothers under 20 years of age and 40-54 year with the highest rates of infant mortality.

When looking at the fatalities by age at deaths, the neonatal (under 28 days) mortality rate was 4.0 deaths per 1,000 live births and the postneonatal (28 days to under one year) mortality rate was 1.9 per 1,000 in 2013. Among Hispanic women, Puerto Rican mothers had the highest neonatal mortality rate (4.2 per 1,000), higher than the overall and that of non-Hispanic white women (3.3 per 1,000). Mexican (1.4 per 1,000) and Central South American (1.2 per 1,000) mothers had postneonatal rates lower than the Hispanic and white mothers rate (1.7 per 1,000) (Table 2) (Mathews et al., 2015).
1.2.2.2 Leading causes of death

The top five leading causes of infant deaths in 2013 accounted for 57% all infant deaths. The causes were congenital malformations (20% of all infant deaths), disorders related to short gestation and low birth weight (18%), maternal pregnancy complications (7%), sudden infant death syndrome (7%), and unintentional injuries (5%). The same top four causes of deaths were seen among infants of Hispanic women in 2013, but for Mexican Hispanic women the top causes of mortality were disorder related to short gestation and low birthweight, congenital malformations, maternal pregnancy complications, and sudden infant death syndrome (Mathews et al., 2015).

Table 1: Infant Mortality Rates by Selected Characteristics and Geography, 2013.

<table>
<thead>
<tr>
<th>Selected Characteristics</th>
<th>U.S.</th>
<th>Arizona</th>
<th>California</th>
<th>New Mexico</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rates per 1,000 live births</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>6.0</td>
<td>5.7</td>
<td>4.7</td>
<td>5.9</td>
<td>5.8</td>
</tr>
<tr>
<td>Race/Ethnicity of Mother</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>5.0</td>
<td>5.6</td>
<td>4.6</td>
<td>6.1</td>
<td>5.3</td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>5.1</td>
<td>4.7</td>
<td>3.9</td>
<td>4.0</td>
<td>5.1</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>11.1</td>
<td>11.1</td>
<td>9.4</td>
<td>9.0</td>
<td>10.7</td>
</tr>
<tr>
<td>American Indian or Alaskan Native</td>
<td>7.6</td>
<td>8.5</td>
<td>5.9</td>
<td>8.3</td>
<td>*</td>
</tr>
<tr>
<td>Asian or Pacific Islander</td>
<td>4.1</td>
<td>5.1</td>
<td>3.8</td>
<td>3.4</td>
<td>3.8</td>
</tr>
<tr>
<td>Age&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 20 years</td>
<td>8.6</td>
<td>7.3</td>
<td>6.6</td>
<td>6.6</td>
<td>7.4</td>
</tr>
<tr>
<td>20-29 years</td>
<td>6.2</td>
<td>5.7</td>
<td>4.7</td>
<td>5.5</td>
<td>5.6</td>
</tr>
<tr>
<td>30-39 years</td>
<td>5.1</td>
<td>4.8</td>
<td>4.1</td>
<td>6.4</td>
<td>5.3</td>
</tr>
<tr>
<td>40 years and older</td>
<td>7.7</td>
<td>9.1</td>
<td>6.5</td>
<td>6.9</td>
<td>8.5</td>
</tr>
<tr>
<td>Total</td>
<td>6.0</td>
<td>5.7</td>
<td>4.7</td>
<td>5.9</td>
<td>5.8</td>
</tr>
<tr>
<td>Rates per 100 live births</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Birthweight (less than 2,500 grams)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8.0</td>
<td>6.9</td>
<td>6.7</td>
<td>8.9</td>
<td>8.3</td>
</tr>
<tr>
<td>Preterm (under 37 weeks)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>9.6</td>
<td>9.1</td>
<td>8.4</td>
<td>9.3</td>
<td>10.4</td>
</tr>
</tbody>
</table>

Notes. * = Based on fewer than 20 deaths in the numerator figure does not meet standard for reliability or precision.
Source: Mathews et al., 2015.
<sup>a</sup> Source: National Center for Health Statistics [NCHS], 2017.
<sup>b</sup> Data from 2011-2013 average.
<sup>c</sup> Source: National Center for Health Statistics [NCHS], 2017.
1.2.2.3 Other factors related to infant mortality

Two factors that are associated with infant mortality are prematurity (born under 37 weeks of gestation) and low birthweight (born weighing less than 2,500 grams). In 2013, 11.4% of all births were preterm, and 8.1% of infants were born with low birth weight (Mathews et al., 2015).

Prematurity is the most important predictor of an infant’s survival, and later health since being born too early or small has a higher risk of death and disability compared to infants born at full term (39-40 weeks of gestation) (Mathews et al., 2015). Infant mortality is usually the highest for very preterm (under 32 weeks) infants, and the risk decreases with increased gestational age. Because of this higher risk of death, prematurity has a more significant impact on mortality rates (Mathews et al., 2015). In 2013, 11.4 percent of infants in the U.S. were born preterm and 67% percent of the deaths in this year were among premature infants. In addition,
there are significant disparities in the proportions of preterm births and gestational specific infant deaths by race and ethnicity, which disproportionally affect the IMR of some race and ethnic groups. In the U.S. non-Hispanic, black women had the highest proportion of preterm births, 16.3% and non-Hispanic white and Asian or Pacific Islander women had the lowest percentages, with 10.2% each. Approximately 11.3% of Hispanic births were preterm, and among this group, Mexican women had the lowest proportions with 10.8% (Mathews et al., 2015).

Birthweight also is a predictor of an infant’s survival, and although it is associated with the period of gestation, it does not precisely correspond with it. Like prematurity, infant mortality is highest for the lowest weight infants, and the risk decreases as birthweight increases (Mathews et al., 2015). Because of this higher risk of death among very low birthweight (VLB) (less than 1000 grams) infants, it has a significant impact on the IMR. In 2013, 47.2% of all deaths were among infants weighing less than 1,000 grams, while they only comprised 0.7% of all births. Disparities in the proportions of births at low birthweight are also seen as with prematurity. In 2013, non-Hispanic black women had the highest proportion of low birth weight, 13.1%, while Hispanic women were 7.1%, similar to non-Hispanic white women, 7.0% and Mexican women 6.6% (Mathews et al., 2015).

1.2.2.4 Border states and county rates

In 2013, infant mortality rates in the U.S. border states ranged from were 4.7 deaths per 1,000 live births in California to 5.9 per 1,000 in New Mexico (Table 1). The four border states had lower IMR than the U.S. national rate of 6.0 per 1,000, and California was the border state with the lowest rates. Overall, IMR in the border states has followed the U.S. trend and decreased since 2005 (Centers for Disease Control and Prevention, 2017; Mathews et al., 2015; Matthews & Driscoll, 2017).

The border states follow the same national trend when it comes to disparities in infant mortality by race and ethnicity. In each of the border states, non-Hispanic Black women had the highest rates of infant mortality, while non-Hispanic white women and Asian/Pacific Islander
mothers had the lowest rates of all race/ethnic groups (Table 1). In all four border states, Hispanic women fell in the middle when it came to infant mortality rates. California had the lowest IMR among Hispanic women (4.6 per 1,000) of the four border states and nationally (5.0 per 1,000). New Mexico had the highest IMR among Hispanic which was 6.1 per 1,000 in 2013 (Mathews et al., 2015).

Likewise, the border states followed the same national trend to infant mortality by maternal age. Nationally and in the four states, women under 20 years of age and women over 40 years old had the highest rates (Table 1). In all border states, except for New Mexico, women between 30-39 years of age had the lowest rates of infant deaths. In New Mexico, women between 20-29 years old had the lowest rates of infant mortality (National Center for Health Statistics, 2017b).

The rates for prematurity and low birthweight differed among the border states. In 2013 New Mexico and Texas had higher low birthweight and prematurity rates than the U.S. national rates for each (Table 1). California had the lowest rates for low birthweight of 6.9% and prematurity of 8.4% (National Center for Health Statistics, 2017a).

1.2.2.5. U.S.-Mexico Border Region rates

The data available for the U.S. Border region overall is limited and outdated. Some of the existing data do show some existent disparities. Data from 2005-2007 show that the average IMR for the border states combined was 5.8 deaths per 1,000 live births and for the border counties was 5.4 per 1,000. Both rates were lower than the U.S. notional IMR for this period of 6.8 per 1,000 (March of Dimes Perinatal Data Center, 2011).

Preterm births in the border counties (12.5%) was similar to the national average (12.6%). However, border states combined (12.0%) had lower preterm rates than the border counties and the U.S. rates. Interestingly, preterm births were higher among Hispanics than non-Hispanic whites in the border counties (12.9% vs. 10.4%), the border states (12.0% vs. 11.2%), and the U.S. (12.2% vs. 11.4) from 2006-2008 (March of Dimes Perinatal Data Center, 2011).
Also, the border counties and border states had lower births resulting in low birth weight, 7.4%, and 7.5%, respectively, than the U.S. rate of 8.2% from 2006-2008. Births resulting in low birthweight were higher among Hispanics than non-Hispanic whites only in the border counties (7.3% vs. 6.6%) (March of Dimes Perinatal Data Center, 2011).

1.3 Proposed Methods for Reducing Infant Mortality

1.3.1 Life Course Theory

Life Course Theory (LCT) is an interdisciplinary framework developed to explain health and disease across populations and time. Also, it offers a new model for addressing racial and ethnic disparities in maternal and child health (Cheng & Phillips, 2014; Fine & Kotelchuck, 2010; Pies, Parthasarathy, Kotelchuck, & Lu, 2009). In contrast, to the traditional maternal and child health approach to disease and health being specific to separate stages from infancy to old age, LCT looks at health as an integrated continuum from conception to death. It recognizes a complicated relationship of social determinants that contribute to persistent inequalities in health and health outcomes across the course of a person’s life (Fine & Kotelchuck, 2010; Pies et al., 2009).

Social determinants unfavorably impact health and birth outcomes when education, healthy food, safe housing, transportation, and sustainable salaries are not available or are difficult to acquire (Pies et al., 2009). Furthermore, persistent health inequities among minority groups and the poor are directly related to their living conditions and personal experiences (Pies et al., 2009), and these elements should be addressed in any plan to improve birth outcomes.

LCT suggests that interventions that decrease risks and increase protective factors can change the health trajectory of individuals and populations (Fine & Kotelchuck, 2010; Pies et al., 2009). Therefore, strategies should have a greater emphasis on “upstream” determinants of health by focusing on earlier interventions and aim to reduce risk factors, while at the same time promoting protective health factors for individuals, families and the communities (Fine & Kotelchuck, 2010). For example, an obesity prevention program that focuses on healthy eating
for all family members, adults, and children, to maintain a healthy weight will produce children that grow up to have a healthy weight, and thus resulting in adults that are healthier and women that can have healthy pregnancies.

Therefore, LCT provides a framework to examine adverse birth outcomes and the inequities in infant mortality through a focus rooted in social determinants and social fairness. LCT tries to accomplish this by focusing on four essential elements: Timeline, timing, environment, and equity.

Timeline refers to concentrating efforts on improving health within a person’s lifetime and across generations. Timing refers to focusing on limiting risk factors that affect health earlier in life, and at critical moments over an individual’s life trajectory, such as in early childhood, adolescence, young adulthood, and before pregnancy. Environment refers to understanding and targeting social, physical, and economic factors that influence health and health outcomes. Finally, equity relates to understanding that disparities in social determinants among populations lead to inequalities in health across these same groups (Fine & Kotelchuck, 2010).

### 1.3.2 Perinatal Periods of Risk

A standardized approached used in communities to examine and address the specific local causes of fetal and infant mortality and disparities within groups is the Perinatal Periods of Risk (PPOR) framework (CityMatch, 2008; Peck et al., 2010; Sappenfield et al., 2010a). PPOR was developed by McCarthy (1997) with the World Health Organization (WHO) for using it in other countries, and then adapted, improved, and validated by CityMatCH, with the support of the CDC, HRSA, WHO, and March of Dimes (CityMatch, 2008). PPOR had been used in over 100 U.S. communities to help determine population-based activities to lower IMR, such as in St. Louis, Jacksonville, and Kansas (Sappenfield et al., 2010a).

PPOR provides a more complete approach in analyzing infant deaths because it utilizes data from both linked birth-infant deaths and fetal deaths datasets to construct more detailed
analyses of factors associated with fetal and infant mortality (Burns, 2005; CityMatch, 2008; Peck et al., 2010; Sappenfield et al., 2010a). The inclusion of fetal death data is beneficial because traditional infant mortality calculations do not consider in utero deaths when providing the rate of population-specific infant mortality. Therefore, standard infant mortality rates are limited for understanding early infant deaths and developing approaches to reduce the risk of an infant dying (Crump et al., 2011; Sappenfield et al., 2010a). PPOR can establish risk factors for each developmental stage for an adverse birth outcome by operationalizing the classification of fetal and infant deaths into four Perinatal Periods of Risk based on birth weight and age at death (CityMatch, 2008). Each fatality is mapped into a matrix containing the four PPOR based on birthweight (500g-1499g and 1500+ grams) and age (fetal, neonatal, and postnatal) (see Figure 1). These categorizations into each of the periods are hypothesized to be associated with a different cause of death, allowing for further investigations into risk factors of the fetal and infant deaths (Sappenfield et al., 2010a). Also, using age at death and birthweight are an essential component of the approach because risk factors differ for low birth weight and mortality (Burns, 2005; Peck et al., 2010; Sappenfield et al., 2010a).

Four strategic prevention areas guided the conceptualization of the periods of risk and included Maternal Health/Prematurity (MHP), Maternal Care (MC), Newborn Care (NC), and Infant Health (IH). These prevention areas defined periods of risks and are helpful because causes of death tend to be similar within each. When problems lie in only one or two periods of risk, targeted intervention strategies can be designed specifically for those stages (see Figure 2) (CityMatch, 2008; Sappenfield et al., 2010a). For instance, if the majority of the excess deaths are in the MHP period, then efforts can target preconception health, health behaviors, and perinatal care. Alternatively, if IH has the highest excess deaths, then interventions might focus on improving safe sleep, breastfeeding, and injury prevention.
Age at death

Fetal deaths (>= 24 weeks of gestation)

Neonatal (0-27 day of life)

Postnatal (28-365 day of life)

500-1,499 grams

Maternal Health /Prematurity

Maternal Care

Newborn Care

Infant Health

≥ 1,500 grams

Figure 1: Feto-infant Mortality PPOR Map.

Potential Action

Preconception Health
Health Behaviors
Chronic Diseases
Perinatal Care

Prenatal Care
High Risk Referral
Obstetric Care

Perinatal Management
Neonatal Care
Pediatric Surgery

Safe-Sleep
Breast Feeding
Injury Prevention

Figure 2: Perinatal Periods of Risk and primary prevention areas.
The PPOR is divided into two analytic phases. Phase 1 identifies the IMR of fetal and infant mortality cases, and the rate is then compared to a reference group of mothers with optimal birth outcomes to estimate the excess deaths for each PPOR. This reference group provides a realistic benchmark to strive for in a community and allows for estimation of preventable (excess) deaths for each period of risk. The period with the most excess deaths become the focus of further investigation to determine the known causes that are most likely influential in that period of risk in phase 2 (CityMatch, 2008; Peck et al., 2010; Sappenfield et al., 2010a; Sappenfield, Peck, Gilbert, Haynatzka, & Bryant III, 2010b). Phase 2 systematically investigates the “opportunity gaps” or period of risk with the highest excess deaths found in Phase 1 to determine what risk and preventative factors will have the greatest impact on reducing the IMR in a community (Sappenfield et al., 2010b). Standard epidemiological methods are used in this phase to identify the pathways or mechanism for excess deaths by estimating the prevalence risk, preventative factors, and the impact of the risk ((Sappenfield et al., 2010b; Xaverius et al., 2014). Then the prevalence of risk and preventative factors and the impact of the factors are estimated in the specific PPOR of study (Sappenfield et al., 2010b). Using this approach in the border region can identify groups and regions to target further investigations and focus prevention efforts.

1.4 Vital Records in the U.S.

Vital records registration has been in existence in the U.S. since 1902 when Congress established the Bureau of Census and gave it legal authority to develop registration capacities for vital records. In 1946, the Public Health Service Act transferred function of collecting vital statistics to the U.S. Public Health Service and presently this function is assigned to the Division of Vital Statistics of the National Center for Health Statistics (NCHS) at the Centers for Disease Control and Prevention (CDC) (National Center for Health Statistics, 2000). Currently, vital statistics are collected through a decentralized system. The responsibility of registering vital events, such as births and deaths, falls on the individual states, but the uniformity of the records
is achieved through recommended standards from NCHS and cooperation of the states to adopt the regulations (National Center for Health Statistics, 2000; National Center for Health Statistics, 2016a).

The NCHS collaborates with states to improve the quality, timeliness, and usefulness of health data through the Vital Statistics Cooperative Program (VSCP). The standard certificates include the minimum necessary data needed for the collection and publication of comparable national, state, and local data. Also, the standards are used as a model for states to develop their forms for registration of vital events (National Center for Health Statistics, 2000). Approximately every 10-15 years, the U.S. standard certificates are reviewed to ensure they still meet the current data needs (National Center for Health Statistics, 2000; National Center for Health Statistics, 2005; National Center for Health Statistics, 2016a).

The twelfth revision of the U.S. Standard Certificate of Live Births and the U.S. Standard Certificate of Deaths took effect in 2003. Although uptake of the 2003 death certificate was quicker in most states, implementation of the birth certificate was slow, and many states continued using the eleventh revision of 1989 for the collection of birth records until January 1, 2015. One of the last states to adopt the twelfth revision was Arizona which implemented the 2003 Standard Certificate of Live Births in 2015 (National Center for Health Statistics, 2014a). As a consequence, birth data before 2015 for the border region states were collected through two different instruments. The 1989 U.S. Standard Certificate of Live Birth was used in Arizona, and the 2003 U.S. Standard Certificate of Live Birth was used in California, New Mexico, and Texas. The use of two collection instruments in the border region could significantly affect the reliability and validity of 2003-2014 birth datasets, which are often used in pregnancy outcome surveillance and epidemiological research in the area.
1.4.1 Background on U.S. Standards Certificate

1.4.1.2 1989 U.S. Standard Certificate of Live Birth

A thirty-member panel developed the 1989 U.S. Standard Certificate of Live Birth, convened by NCHS to replace the 1978 revision of the standard certificate (Freedman, Gay, Brockert, Potrzebowski, & Rothwell, 1988; Tolson, Barnes, Gay, & Kowaleski, 1991) and implementation in states began on January 1, 1989 (Tolson et al., 1991). The panel consisted of experts that included state vital registration and statistics executives, healthcare providers, professional organizations, and data users. The committee was divided into a ten-member principle group that oversaw the entire process, and six subgroups made up of the remaining members of the panel. Each of the subgroups oversaw one aspect of the revision, which included the birth certificate, the death certificate, the marriage and divorce certificates, the fetal death and induced termination of pregnancy reports, the format of all certificates, and assessment of the Model State Vital Statistics Act and Regulations (Freedman et al., 1988; Tolson et al., 1991). Further details on the panel proceedings are available elsewhere (Tolson et al., 1991).

Overall the literature suggested that depending on the variables being studied reliability and validity can differ substantially in the 1989 birth certificate data. Data may be reliable for such variables as maternal demographics, type of delivery, and receipt of prenatal care (Baumeister, Marchi, Pearl, Williams, & Braveman, 2000; DiGiuseppe, Aron, Ranbom, Harper, & Rosenthal, 2002; Gould, Madan, Qin, & Chavez, 2003), but less reliable for measuring maternal risk factors and comorbidities and complications of pregnancy and/or labor and delivery, and birth defects (DiGiuseppe et al., 2002; Gould et al., 2003). Therefore, caution needs to be taken when selecting variables to study from the 1989 birth certificate data since evidence of reliability and validity are lacking in some items.

1.4.1.3 2003 U.S. Standard Certificate of Live Birth

The process for the twelfth revision of the U.S. Standard certificates of birth and death began in 1994 with a survey to determine if changes were needed and if items needed to be
added or deleted. The questionnaire was sent to 1,600 state vital registration and statistics executives. After consensus from the states that a revision was needed, a panel of 24 experts consisting of state vital registration and statistics executives, data users, and healthcare organizations was assembled by NCHS. The panel was divided into a principle group that oversaw the entire process, and four subgroups that managed one aspect of the revision, which included birth certificate, death certificate, fetal death certificate, or standards and design (National Center for Health Statistics, 2000).

The birth subgroup began meeting in 1998 to evaluate the standard certificate, which consisted of reviewing the 1989 standard certificate to determine which items to keep, add, change, or delete. In addition, the panel identified topics that would need the testimony of experts and conducted a national survey asking health departments, vital registration and statistics executives, and data user organizations for input on what needed to be updated in the certificates (National Center for Health Statistics, 2000). All this effort led to the new revised standard birth certificate. Further details on the panel proceedings are available elsewhere (National Center for Health Statistics, 2000).

Similar to the 1989 birth certificate, caution needs to be taken when selecting variables to study from the 2003 birth certificate data since evidence of reliability and validity lack in some items. Items such as birth weight, gestational age, prior obstetrical history, race/ethnicity, delivery method, attempted trial of labor, private insurance, and Medicaid may have greater validity and reliability than preterm delivery and occupational information in the 2003 standard certificate (Andrade et al., 2013; Barradas et al., 2014; Brender, Suarez, & Langlois, 2008). A strength of the 2003 birth certificate is that NCHS made significant efforts to standardize the collection of birth data by providing manuals and supplemental materials with instructions, definitions, and guidelines. A weakness of the 2003 birth certificate is that the information of the validity and reliability is not as readily available as are the handbooks and supplemental materials.
1.4.1.4 2003 U.S. Standard Certificate of Death

The death subgroup began meeting in 1998 to evaluate changes needed the standard certificate of death. The group recommended wording changes and the addition of checkboxes to existing certificate items, added items to address public health concerns associated with ICD-9 and ICD-10 coding, and added questions about tobacco use, pregnancy status of female decedents, and traffic deaths. In addition, the group added a section called “For Statistical Use Only” that includes occupation, business/industry, Hispanic origin, race, and education items. This new section was proposed to improve the quality of data for sensitive topics. Also, extensive instructions for the physician and funeral director were added as detachable pages to the certificate. Further details on the panel proceedings are available elsewhere design (National Center for Health Statistics, 2000). NCHS implemented the 2003 U.S. Standard Certificate of Death on January 1, 2003, but uptake by state varied (National Center for Health Statistics, 2000).

Similarly, to the 1989 and 2003 standard birth certificate, the reliability and validity of the 2003 standard death certificate differ widely by item and state. Most categories in the death certificate for race and ethnicity have high reliability, but the cause of death for infants less than one-year-old may have inconsistencies. Also, like the birth certificate NCHS aimed to standardize the collection of death data and is one of the strengths of the revised death certificate, but has the same limitations since information on validity and reliability is not available with the handbooks and supplemental materials.

1.4.1.5 Summary of Birth and Death Standard Certificates

The reliability and validity of the 1989 and 2003 U.S. Standard Birth Certificate of Live Births differ extensively by items and states. In the 1989 certificate, items such as maternal demographics, type of delivery, and receipt of prenatal care had high reliability and accuracy (Baumeister et al., 2000; DiGiuseppe et al., 2002; Gould et al., 2003), but less reliable were items for measuring maternal risk factors, comorbidities and complications of pregnancy, labor
and delivery, and birth defects (DiGiuseppe et al., 2002; Gould et al., 2003). In contrast, in the 2003 certificate items such as birth weight, gestational age, prior obstetrical history, race/ethnicity, delivery method, attempted trial of labor, private insurance, and Medicaid showed high validity and reliability than preterm delivery and occupational information in the 2003 standard certificate (Andrade et al., 2013; Barradas et al., 2014; Brender et al., 2008).

NCHS standardization of the collection of birth data significantly improved the accuracy and precision of many of the items of the 2003 birth certificate, but inconsistencies remain in some items. Since NCHS guidelines are not mandatory, but only recommendations for states to follow, some of the items inconsistencies could be attributed to different procedures of data collection. The same inconsistency in reliability and validity of items are seen in the 2003 standard death certificate. The changes to the race/ethnicity items in the 2003 standard death certificate appear to improve the reliability of race and ethnicity reporting (Fiscella & Meldrum, 2008).

In summary, special care should be taken when using the U.S. Standard Certificate of Live Birth and the U.S. Standard Certificate of Death in the U.S-Mexico Border Region. Reliability and validity can vary significantly depending on the item being studied and the state the certificate information was collected. Therefore, whenever possible, items from vital records should be cross-referenced with other databases. Further research is needed to adequately assess the accuracy of vital records in the border region.

1.5 Statement of the Problem

This study seeks to determine if there are differences in infant mortality and excess death on the U.S. side of the U.S.-Mexico border region. The border area has unique health disparities in reproductive health and limited resources. The research on infant mortality for the border region is scarce and outdated, and there is a gap in the literature of whether specific periods of risks contribute to infant deaths differently than for the U.S. or the border states. Furthermore, the traditional infant mortality indicator cannot indicate causal factors. PPOR analyses,
however, go beyond traditional infant mortality indicators and provide a well-tested and systematic approach for determining in which chronological periods of risk excess infant deaths are occurring for a particular region. This, in turn, can guide community-based inventions with the highest likelihood of reducing infant deaths. Moreover, this study will add to the current body of knowledge regarding excess deaths and infant mortality in the U.S.-Mexico border region.

1.6 RESEARCH QUESTIONS AND HYPOTHESIS

- **Objective 1:** Determine the overall feto-infant mortality rate for the U.S side of the U.S.-Mexico Border Region and compare it to the border states and U.S. national rates.
  - **Research Question 1:** What is the overall feto-infant mortality rate for the U.S. side of the U.S.-Mexico Border Region compared to the U.S. and border states rates?
  - **H$_1$:** The U.S Mexico border region will have higher feto-Infant mortality rates than the combined border states and the U.S. national rates.

- **Objective 2:** Determine if border counties have higher excess feto-infant deaths than non-border counties in the U.S. border states.
  - **Research Question 2:** Are there differences in excess feto-infant deaths in border counties compared to non-border counties in the U.S. border states?
  - **H$_2$:** The U.S. border counties within the U.S. Border States will have higher excess feto-infant deaths than non-border counties within the U.S. Border States.

- **Objective 3:** Determine if there are differences in specific periods of risk that show excess feto-infant deaths in border counties as compared to non-border counties in the U.S. border states.
- **Research Question 3:** Are there differences among the specific periods of risk that show excess feto-infant deaths in border counties compared to non-border counties in the U.S. border states?

- **H₃:** The U.S. border counties within the U.S. Border States will one or more identifiable periods of risk associated with excess feto-infant deaths.

  - **Objective 4:** Determine what risk factors are associated with low birthweight and prematurity in the U.S. Mexico border region.
    - **Research Question 4:** What risk factors are associated with low birthweight and prematurity in the U.S. Mexico border region?
    - **H₄:** Maternal morbidity (diabetes and hypertension), maternal education, and maternal behaviors will be significantly associated with adverse birth outcome (low birthweight and preterm).

  - **Objective 5:** Determine what maternal characteristics are associated with an infant dying in the in the U.S. border states.
    - **Research Question 5:** What maternal characteristics are associated with an infant dying in the U.S. border states?
    - **H₅:** Younger maternal age, low education, and residing in a border county will be associated with a higher risk of infant death in the U.S. border states.

  - **Objective 6:** Determine what factors are associated with the leading cause of death in the PPOR with the highest excess deaths in the U.S Mexico border region.
    - **Research Question 6:** What factors are associated with the leading cause of death in the PPOR with the highest excess deaths in the U.S. Mexico border region?
    - **H₆:** Behavioral factors will be significantly associated with the leading cause of death in the PPOR with the highest excess deaths in the U.S. Mexico border region.
Chapter 2: Methods

2.1 Datasets

Data files that included the state and county variables were requested from the National Center for Health Statistics (NCHS) National Vital Statistics System. The data received included U.S. natality, linked infant birth-death, and fetal death certificates files for years 2004-2013.

The linked birth-death files for years 2009-2013 and fetal deaths files for years 2009-2013 were combined for this study into two separate datasets, one that included all years of infant deaths and one that included all years of fetal deaths. For each dataset, all deaths in which the mother reported a residence outside the U.S. (n=55) were excluded to create datasets that only included deaths residing in the 50 U.S. states.

The datasets included a total of 403,688 mother/infant or fetal dyads. The database was structured such that all maternal characteristics were provided by infant/fetal death (each row represented one infant or fetal death and the mother’s and infant’s characteristics at the time of birth and death).

2.1.1 Infant and fetal mortality datasets

The datasets included 283,016 U.S. fetal deaths and 120,672 linked birth-death certificate infant deaths. The mother's state of residence was used to classify each death as occurring in a border state (Arizona, California, New Mexico, and Texas) or non-border states (all other 46 states). In addition, the maternal county Federal Information Processing Standard (FIPS) codes of residence were used to classify deaths as part of the border or not. Women that indicated living in one of the 44 U.S. border counties were considered border residents. Only three of the U.S. border states had implemented the 2003 revision of the U.S. Standard Certificate of Live Births by 2014. The Arizona data were based on the 1989 version, and some items were not available in a comparable format for Arizona for this study. The items from the 1989 version of the birth certificate that were either not collected or asked differently included mother’s education, smoking during pregnancy, abnormal conditions of the newborn, various congenital
anomalies, mother’s pre-pregnancy weight and height, breastfeeding initiation, infant transfer, various morbidities (i.e., pre-pregnancy diabetes, gestational diabetes) and previous preterm birth. A full list is available in the Natality User Guide for each year of natality data (National Center for Health Statistics, 2010; National Center for Health Statistics, 2011; National Center for Health Statistics, 2012; National Center for Health Statistics, 2013; National Center for Health Statistics, 2014b). Consequently, in this study, some comparisons with these variables were not made for the border region that included Arizona.

2.1.2 Natality dataset

The birth certificate files from 2009-2013 were combined to create a birth dataset (N=19,968,663) that included all years. All live births for which the mother reported residence outside of the U.S. were excluded from the analysis. In addition, all births with missing birth weights, birthweights less than 500 grams, and implausible gestation (see Appendix) and birth combinations were excluded (CityMatch, n.d.). This resulted in 19,907,429 U.S. births. Similar to the death files, mother’s state and county FIPS of residence were used to determine residency in a border state or county. The natality dataset, along with the total number of fetal deaths, was used to calculate the denominator for rate calculations.

2.2 Data Preparation

Based on the methods by Sappenfield et al. (2010a) data quality and validity were assessed in preparation for the analysis. The following procedures were carried out for both datasets.

The number of infant and fetal deaths in the datasets was compared to NCHS published data for the four border states. The percentage differences are shown in Table 3. All differences were less than 2% for the linked infant deaths and less than 1% for fetal deaths. The differences between the published data and the datasets may be due to changes done in data files after the published data were released, such as adoptions that may be amended to the certificate at a later time (Sappenfield et al., 2010a). In addition, the percentage of death certificates for infant deaths
that could not be linked were less than 1.4% for the U.S. and less than 4% for the four border states (Tables 3 and 4). Natality totals did not differ from the data files, and NCHS published numbers for each year studied.

Table 3: Comparison of Published Mortality Numbers and Death Certificate User Files for the United States from 2009-2013.

<table>
<thead>
<tr>
<th>Year</th>
<th>United State Residents</th>
<th>NCHSb</th>
<th>Data user file</th>
<th>Difference</th>
<th>NCHSb</th>
<th>Data user file</th>
<th>Percent difference</th>
<th>Birth-death Certificate Unlinkedc</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>N: 24,872</td>
<td>N: 24,902</td>
<td>%: 0.12</td>
<td>N: 26,408</td>
<td>N: 25,819</td>
<td>%: 2.2</td>
<td>N: 353</td>
<td>%: 1.3</td>
</tr>
<tr>
<td>2010</td>
<td>N: 24,258</td>
<td>N: 24,276</td>
<td>%: 0.07</td>
<td>N: 24,572</td>
<td>N: 24,292</td>
<td>%: 1.1</td>
<td>N: 299</td>
<td>%: 1.2</td>
</tr>
<tr>
<td>2012</td>
<td>N: 24,073</td>
<td>N: 24,108</td>
<td>%: 0.14</td>
<td>N: 23,629</td>
<td>N: 23,444</td>
<td>%: 0.7</td>
<td>N: 229</td>
<td>%: 1.0</td>
</tr>
<tr>
<td>2013</td>
<td>N: 23,595</td>
<td>N: 23,621</td>
<td>%: 0.10</td>
<td>N: 23,446</td>
<td>N: 23,242</td>
<td>%: 0.8</td>
<td>N: 223</td>
<td>%: 1.0</td>
</tr>
</tbody>
</table>

a Includes only fetal deaths 20 weeks of gestation or more.
b Source: National Center of Health Statistics (NCHS) mortality data.

Table 4: Percent of Infant Death Certificates Linked to their Corresponding Birth Certificate by Border State from 2009-2013.

<table>
<thead>
<tr>
<th>Border State</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>97.6</td>
<td>97.5</td>
<td>98.6</td>
<td>99.6</td>
<td>99.1</td>
</tr>
<tr>
<td>California</td>
<td>96.7</td>
<td>97.4</td>
<td>96.2</td>
<td>98.3</td>
<td>98.2</td>
</tr>
<tr>
<td>New Mexico</td>
<td>96.3</td>
<td>99.2</td>
<td>100</td>
<td>99.4</td>
<td>98.4</td>
</tr>
<tr>
<td>Texas</td>
<td>95.3</td>
<td>95.8</td>
<td>95.5</td>
<td>96.6</td>
<td>95.6</td>
</tr>
</tbody>
</table>

The variables birthweight, gestational age, and age at death were examined in each dataset for outliers and impossible combinations of gestation and birthweight of fetuses (see Appendix) (CityMatch, n.d.). Any outliers and improbable combinations were excluded from the analysis. In addition, the percentages of missing data on key variables for PPOR were assessed since missing data can bias the results by falsely lowering the mortality numbers and rates by the amount of the missing data. Since birthweight, gestational age, and age at death were required for the PPOR infant mortality map, the percentage of missing birthweights, unlinked infant deaths, infant deaths with missing birth weight and fetal deaths with missing birthweight or gestational age were calculated.

Missing percentages were also calculated for other variables used in the analysis since they can bias the reference group and comparisons made. The variables that were assessed included maternal age, maternal education, maternal race/ethnicity and county of residence. The missing percentages are shown in Table 5. The variables that had more than 10% of data missing included birthweight (56.3%) in only the fetal death dataset. When restricting the deaths to the PPOR parameter or 24 weeks of gestation or higher, then this percentage was reduced to 19.8% missing. Since this was a critical variable for PPOR analysis, data imputation was used for this variable. For each week of gestation, the mean birthweight was calculated and the mean was used to replace any missing birthweight for a given gestational age. For example, at 24 weeks of gestation, the birthweight mean was 728 grams; therefore all missing birthweights for fetal deaths occurring at 24 weeks of gestation were replaced with this mean. There were 15,717 (17.0%) fetal deaths at 24 weeks of gestation or higher, that had both birthweight and gestation missing and imputation could not be applied to those deaths, and they were excluded from the analyses.
Table 5: Number and percentages of “unknown” for live births, fetal deaths, and infant deaths ineligible for PPOR Study by data element 2009-2013.

<table>
<thead>
<tr>
<th></th>
<th>Live Births</th>
<th>Linked Deaths</th>
<th>Fetal Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Total Deaths(^a)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unlinked deaths</td>
<td>NA(^b)</td>
<td>NA(^b)</td>
<td>1,403</td>
</tr>
<tr>
<td>All births, linked infant deaths, and fetal deaths</td>
<td>n = 19,968,663</td>
<td>n = 120,672</td>
<td>n = 283,016</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key analysis variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birthweight</td>
<td>21,019</td>
<td>0.11</td>
<td>606</td>
</tr>
<tr>
<td>Gestational age</td>
<td>23,170</td>
<td>0.12</td>
<td>1,051</td>
</tr>
<tr>
<td>Gestational age or birthweight</td>
<td>39,638</td>
<td>0.20</td>
<td>10,511</td>
</tr>
<tr>
<td>Age at Death</td>
<td>NA(^b)</td>
<td>NA(^b)</td>
<td>0</td>
</tr>
<tr>
<td>Mother's State of Residence</td>
<td>413</td>
<td>&lt; 0.01</td>
<td>10</td>
</tr>
<tr>
<td>Mother's County of Residence</td>
<td>413</td>
<td>&lt; 0.01</td>
<td>10</td>
</tr>
<tr>
<td>All PPOR eligibles(^c)</td>
<td>n = 19,907,429</td>
<td>n = 92,282</td>
<td>n = 63,283</td>
</tr>
<tr>
<td>Other analysis variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother's Age</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Mother's Race/Ethnicity</td>
<td>143,082</td>
<td>0.72</td>
<td>1,836</td>
</tr>
</tbody>
</table>

\(^a\) Raw data files that include all linked infant or fetal deaths for the 50 U.S. states.

\(^b\) Not applicable characteristics of live births or fetal deaths.

\(^c\) These events meet PPOR study requirements.

### 2.3 Study Sample

Period linked birth-infant death datasets were used for each year of study from 2009-2013. The death cohorts included infants that died before reaching one year of age for each year even if they had been born the prior year. Based on PPOR methodology (Sappenfield et al., 2010a), all infant and fetal deaths that were less than 500g, and all fetal deaths less than 24 weeks of gestation were excluded from the analysis. Most states required reporting for fetal deaths at 20 weeks of gestation or 350 grams, (which is equivalent to 20 weeks or a combination
of these two criteria, > 20 weeks and 350 grams) (Fetal death layout 2014). During the years of study (2009 – 2013), Arizona, California, and New Mexico required fetal death reporting starting at 20 weeks of gestation or 350 grams. Texas required reporting starting at 20 weeks of gestation (Fetal death layout 2014) and included no weight criteria. This resulted in a study sample consisting of 155,565 U.S. eligible feto-infant deaths.

In addition, maternal county FIPS and state of residence were used to categorize mothers as living in a border state, living in a border county in the border states, or living in non-border counties in the non-border states.

There were 155,565 feto-infant deaths (63,283 fetal and 92,282 infant deaths) meeting the PPOR definition ($\geq$ 500 grams fetal and infant deaths and fetal deaths $\geq$ 24 weeks of gestation) in the U.S. for 2009-2013. In the four border states there were 34,873 feto-infant deaths (14,375 fetal and 20,498 infant deaths) and in the border counties in the border states there were 3,779 feto-infant deaths (1,551 fetal and 2,228 infant deaths).

2.4 Reference Group

To identify an optimal reference group, the mortality rates for various possible reference groups were calculated. These included, Hispanic women, age 20-34 residing in the U.S.; non-Hispanic white women, age 20-34 residing in the US; non-Hispanic White women, age 20-35 and 20-29 residing in the Border states; Hispanic women, age 20-34 and 20-29 residing in a border state, non-Hispanic white women, age 20-34 and 20-29 residing in a non-border county in a border state; Hispanic women, age 20-34 and 20-29 residing in a non-border county in a border; Hispanic women, age 30-34 residing in California and non-Hispanic women, age 20-34 residing in California. The optimal group identified included non-Hispanic white mothers between 20-34 years of age residing in California, (n=2,968) and had a feto-infant mortality rate of 5.5 per 1,000 live births and fetal deaths. Education was not included in the reference group because from 2009-2013, NCHS did not provide this variable in the fetal datasets (National Center for Health Statistics, 2015). The low feto-infant mortality rates of this group represented
the benchmark that all groups could obtain. It should be noted that this reference group differed from other PPOR protocols and the results of this study may not be directly comparable to PPOR studies conducted using other reference groups.

2.5 Data Analysis

All analyses were conducted using SAS™ software (Version 9.4, Cary, IN, USA). The files were checked and cleaned to produce analyzable datasets for analysis as described above. Descriptive statistics were calculated for infant and maternal demographic and health characteristics for the combined border states, for the 44 U.S. border counties in the four border states, for the non-border counties in the four border states and the U.S. overall. The previously defined PPOR framework (see page 12-15 above, chi-square and odds ratios were used to characterize and compare feto-infant deaths within and across the U.S.-Mexico border region counties, non-border region counties and in comparison, to the rest of the U.S.

2.5.1 PPOR Phase I

The overall feto-infant mortality was assessed for four periods of risk including Maternal Health/Prematurity (MHP), Maternal Care (MC), Newborn Care (NC), and Infant Health (IH) by using the feto-infant mortality map (see Figure 1). The two variables used in the PPOR maps were birthweight and age at death. First, birthweight was divided into two groups, those 500-1499 grams, and those 1500 grams and more. Then age at death was divided into three groups, fetal deaths (died at 24 weeks of gestation or more), neonatal (died within 0-27 days), and postnatal (died within 28-364 days). Each of the fetal and infant death counts was entered onto the map in one of the perinatal periods of risk. This was done for each border state (Arizona, California, New Mexico, and Texas), for the combined border states, for the 44 U.S. border counties in the four border states, and the non-border counties in the four border states. For each of these geographic regions, the overall rates were calculated by adding the infant deaths for each of the four periods (see illustration 1). This was also done for the reference group. Differences were tested for significance by using the chi-square test.
**Overall rate** = \( \frac{\text{# deaths in period } a}{\text{# of live births and fetal deaths}} + \frac{\text{# deaths in period } b}{\text{# of live births and fetal deaths}} + \frac{\text{# deaths in period } c}{\text{# of live births and fetal deaths}} + \frac{\text{# deaths in period } d}{\text{# of live births and fetal deaths}} \)

Illustration 1: Equation to calculate the feto-infant mortality rates in the PPOR analysis.

For each of the regions, the excess mortality was calculated by subtracting the reference group overall rate from the study populations mortality rate (see illustration 2). Likewise, the period-specific excess mortality rates were calculated by subtracting the reference population mortality rate of a period from the overall study population for the same period.

\[
\text{Population (i)excess mortality rate (j)} = \text{Population (i)excess mortality rate (j)} - \text{reference population mortality rate (j)}
\]

Where i=overall or subpopulation and j= overall or perinatal risk period

\[
\text{Population(i) excess number of deaths (j)} = \text{Population (i)excess mortality rate (j)} \times \text{Population (i) number of live births and fetal deaths}
\]

Where i=overall or subpopulation and j= overall or perinatal risk period.

Illustration 2: Equation to calculate the excess deaths in the PPOR analysis.

2.5.2 PPOR Phase II

Further analysis was performed as outlined by Sappenfield et al. (2010b), for the PPOR that had the highest rate of preventable deaths in Phase 1 of the PPOR approach for the border counties.
The Kitagawa formula was used to estimate whether excess deaths were attributable to a higher number of prematurity or very low birthweight (VLBW) babies (birthweight distribution, or to higher deaths rates once born at that birthweight (birth weight-specific mortality rates). These estimates were used to further understand possible causes of low birthweight and prematurity in the border region. Determining which of these two pathways contributed to excess mortality was important because risk factors and interventions for VLBW are different than those for birthweight-specific deaths. For instance, low birth weight births are usually related to behavioral, economic, social, and health disparities of mothers and the focus of any interventions switches from preventing excess deaths to preventing VLBW. In contrast, weight-specific mortality is generally related to medical care provided to the mother and infant during pregnancy and after birth (Sappenfield et al., 2010b).

Following the suggested formula, to examine the contributions of these pathways, birthweight of fetal and infant deaths were categorized into seven ranges of 500-749, 750-999, 1,000-1,249, 1,250-1,499, 1,500-1,999, 2,000-2,499, and 2,500-6,499 grams. Birthweights of live births for the border regions were also divided into these ranges for use as denominators. In addition, these classifications were also done for the birthweight of the reference group. Once the pathway was determined the risk factors associated with that pathway were identified based on Sappenfield et al. (2010b) methods and the prevalence of the risk factors were compared in the target and reference populations. The Attributable Risk Percentages (PAR %) were calculated for the identified risk factors; Chi-Square test was used to test the statistical significance of the differences.

These pathway factors for VLBW were also analyzed using logistic regressions model to determine which risk factors were associated with very low birth weight births in the target population and the reference group. Crude and adjusted odds ratios (OR) were calculated for all variables in the model, and model diagnostics were performed.

Additionally, maternal characteristics including medical risks (i.e., having hypertension or diabetes); education (< 13 years and ≥ 13 years); being married; smoking during pregnancy;
and late or no prenatal care, were examined to determine the likelihood of an infant dying in the U.S. border states versus in the rest of the U.S. overall. Chi-Square were used to test the statistical significance of differences between groups. Values of p<0.01 were considered significant.
Chapter 3: Results

3.1 DESCRIPTIVE CHARACTERISTICS OF FINDINGS

3.1.1 Descriptive characteristics of mothers experiencing fetal and infant deaths in border states as compared to U.S. population

Table 6 shows the descriptive statistics for selected characteristics among PPOR eligible fetal and infant deaths by the geographical regions studied. The percentage distribution of fetal deaths versus infant deaths that occurred in the border states (41.2% fetal and 58.8% infant deaths) and the U.S. (40.7% fetal and 59.3% infant deaths) was similar. There were small differences in the percent distribution of age at death between the border states and the U.S. In the U.S. slightly more infant deaths occurred after 28 days, 25.6%, compared to the border states, 24.6%. Thus, in the border states more infants died at a younger age. Among the border state fetal/infant deaths, the percent distribution that was born very low birth weight (VLBW) (500 - 1,499 grams) (37.6%) was less than the fetal/infant that died in the U.S (38.0%). While the percent distribution of feto-infant death born low birth weight (LBW) (1,500-2,499 grams) was slightly more in the border states (24.0%) compared to the U.S. (23.4%). Thus, in the border states more of the fetal/infant deaths were born LBW and less where born VLBW compared to the feto-infant deaths in the U.S. Likewise, the distribution of percentages for prematurity (< 37 weeks of gestation) was slightly lower in the border states (56.3%) as compared to the U.S. (57.1%). Thus slightly more infants were born full term in the border states.

In the border states, more of the women that experienced a feto-infant death, 39.5% were Hispanic, but in the U.S. 17.3% were Hispanic. These percent distributions were similar to the population estimate of race/ethnic distribution in each region. In the border states, a slightly greater proportion of younger women (less than 20 years of age) and older women (35 years of age and older) experienced a feto-infant death compared to the U.S. Also, women experiencing a feto-infant death in the border states had lower education attainment overall (<12 years of education = 28.4%, 12 years = 30.8%, and ≥ 13 years = 40.8%) compared to the U.S. (<12 years of education = 25.0%, 12 years = 31.4%, and ≥ 13 years = 43.5%). In the border states a larger
percentage of the women were married (49.7%) than in the U.S (47.1%). When it came to pregnancy and labor characteristics, the initiation of first trimester prenatal care among these women were similar in both regions, however among women initiating prenatal care in the third trimester or having no prenatal care, the percentage distribution was slightly higher in the border states (border states= 5.3% 3rd trimester prenatal care and 6.6% no prenatal care vs. U.S. = 4.9% 3rd trimester prenatal care and 6.3% no prenatal care). In the border states, more women had C-sections compared to women in the U.S. (38.9% vs. 37.9%). Also, a smaller percentage of the women that experienced a feto-infant death in the border state had diabetes (7.0% vs. 7.3), hypertension (8.2% vs. 9.7%), and smoked during pregnancy (5.6% vs. 16.4%).

3.1.2 Descriptive characteristics of mothers experiencing fetal and infant deaths in border counties as compared to non-border counties, in border states

As discussed above, in border states, as compared to the U.S. population, it appeared that fetal/infant deaths occurred at earlier ages. When border and non-border counties were compared, this difference was more in border counties. While fetal death percentages were nearly the same, there were slightly higher percentages of infant deaths occurring between 0 and 6 days in border counties (24.6% vs. 24.2%) and slightly less at 28 days or older (24.4% vs. 24.7%). Thus, in the border counties, more infants died at a younger age. While the border states had a greater percentage of the fetal infant deaths being born at LBW, the birthweight percentage distribution in the border and non-border counties was similar, and in the border counties, slightly fewer fetal/infant deaths were associated with VLBW (37.1% vs. 37.7%). In the border counties, more of the fetal and infant deaths were premature births (<37 weeks of gestation) as compared to the non-border counties, (57.0% and 56.2%, respectively). The percent distribution for Hispanic women experiencing a feto-infant death was larger in the border counties, 56.4% compared to the non-border counties, 37.4%. As in the border states and U.S. comparison, these proportions are consistent with the census population distribution estimates of the regions. Also, a larger proportion of the women in the border counties were younger (<20 years of age = 13.3% and 20-24 years of age = 26.2%) as compared to the non-border counties (<20 years of age =
11.5% and 20-24 years of age = 24.5%). Moreover, the border counties had more of the women being under 20 years of age than any of the other regions being compared.

The women that experienced a fetal/infant death in the border counties also had a lower educational attainment (< 12 years of education = 31.5%, 12 years = 30.0%, and ≥ 13 years = 38.5%) as compared to the non-border counties (< 12 years of education = 28.1%, 12 years = 30.9%, and ≥ 13 years = 41.1%). The distribution of non-border county educational attainment was more similar to the percentages seen in the border states. In the border counties a larger percentage of women were married (51.6%) than in the U.S (49.4%). When looking at pregnancy and labor characteristics, more border county women had prenatal care initiation in the first trimester (68.4%) as compared to non-border county women (66.3%). Also, more of the border county women experiencing a fetal/infant death as compared to the non-border county had a C-section (44.2% vs. 38.3%), and diabetes (8.5% vs. 6.8%), but fewer smoked during pregnancy (3.1% vs. 7.0%).

Whether and how the observed differences described above were statistically significant will be discussed in detail below.

### 3.2 PPOR Phase I Results

Tables 7 and 8 show the results of the PPOR Phase I analysis by geographic region and border state. Please note that for these analyses, many calculations had to be performed in addition to those needed to address the study objectives.
Table 6: Selected Characteristics of PPOR Eligible Feto-infant Deaths by Geographical Regions from 2009-2013.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Border Counties(^a)</th>
<th>Non-border Counties(^b)</th>
<th>Border States(^c)</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feto-infant Deaths(^d)</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Fetal</td>
<td>3,779</td>
<td>31,094</td>
<td>34,873</td>
<td>155,565</td>
</tr>
<tr>
<td>Infant</td>
<td>1,551</td>
<td>41.0</td>
<td>12,824</td>
<td>41.2</td>
</tr>
<tr>
<td>Under 6 days</td>
<td>929</td>
<td>24.6</td>
<td>7,536</td>
<td>24.2</td>
</tr>
<tr>
<td>7-27 days</td>
<td>376</td>
<td>9.9</td>
<td>3,061</td>
<td>9.8</td>
</tr>
<tr>
<td>28 days or older</td>
<td>923</td>
<td>24.4</td>
<td>7,673</td>
<td>24.7</td>
</tr>
<tr>
<td>Infant Sex</td>
<td>3,779</td>
<td>31,094</td>
<td>34,873</td>
<td>155,565</td>
</tr>
<tr>
<td>Male</td>
<td>2,066</td>
<td>54.7</td>
<td>17,073</td>
<td>54.9</td>
</tr>
<tr>
<td>Birthweight</td>
<td>3,765</td>
<td>30,973</td>
<td>34,736</td>
<td>154,909</td>
</tr>
<tr>
<td>500-1,499 grams</td>
<td>1,396</td>
<td>37.1</td>
<td>11,674</td>
<td>37.7</td>
</tr>
<tr>
<td>1,500-2,499 grams</td>
<td>915</td>
<td>24.3</td>
<td>7,425</td>
<td>24.0</td>
</tr>
<tr>
<td>Prematurity(^e)</td>
<td>1,454</td>
<td>38.6</td>
<td>11,874</td>
<td>38.3</td>
</tr>
<tr>
<td>Under 37 weeks of gestation</td>
<td>1,267</td>
<td>57.0</td>
<td>10,238</td>
<td>56.2</td>
</tr>
<tr>
<td>Maternal Characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race and Ethnicity</td>
<td>3,779</td>
<td>31,094</td>
<td>34,873</td>
<td>155,565</td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>735</td>
<td>19.5</td>
<td>9,457</td>
<td>30.4</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>182</td>
<td>4.8</td>
<td>4,666</td>
<td>15.0</td>
</tr>
<tr>
<td>Hispanic</td>
<td>2,132</td>
<td>56.4</td>
<td>11,625</td>
<td>37.4</td>
</tr>
<tr>
<td>Other</td>
<td>629</td>
<td>16.6</td>
<td>4,975</td>
<td>16.0</td>
</tr>
<tr>
<td>Unknown</td>
<td>101</td>
<td>2.7</td>
<td>371</td>
<td>1.2</td>
</tr>
<tr>
<td>Age</td>
<td>3,779</td>
<td>31,094</td>
<td>34,873</td>
<td>155,565</td>
</tr>
<tr>
<td>&lt; 20 years</td>
<td>504</td>
<td>13.3</td>
<td>3,561</td>
<td>11.5</td>
</tr>
<tr>
<td>20-24 years</td>
<td>991</td>
<td>26.2</td>
<td>7,638</td>
<td>24.6</td>
</tr>
<tr>
<td>25-29 years</td>
<td>919</td>
<td>24.3</td>
<td>7,792</td>
<td>25.1</td>
</tr>
<tr>
<td>30-34 years</td>
<td>750</td>
<td>19.9</td>
<td>6,510</td>
<td>20.9</td>
</tr>
<tr>
<td>35-39 years</td>
<td>422</td>
<td>11.2</td>
<td>4,023</td>
<td>12.9</td>
</tr>
<tr>
<td>≥ 40 years</td>
<td>393</td>
<td>5.1</td>
<td>1,570</td>
<td>5.1</td>
</tr>
<tr>
<td>Education(^f)</td>
<td>1,276</td>
<td>16.2</td>
<td>18,582</td>
<td>24.0</td>
</tr>
<tr>
<td>&lt; 12 years</td>
<td>586</td>
<td>31.5</td>
<td>4,692</td>
<td>28.1</td>
</tr>
<tr>
<td>12 years</td>
<td>558</td>
<td>30.0</td>
<td>5,160</td>
<td>30.9</td>
</tr>
<tr>
<td>≥ 13 years</td>
<td>718</td>
<td>38.5</td>
<td>6,868</td>
<td>41.1</td>
</tr>
<tr>
<td>Marital Status</td>
<td>3,159</td>
<td>24,182</td>
<td>27,341</td>
<td>142,857</td>
</tr>
<tr>
<td>Married</td>
<td>1,630</td>
<td>51.6</td>
<td>11,952</td>
<td>49.4</td>
</tr>
<tr>
<td>Pregnancy/labor Characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prenatal Care Initiation(^g)</td>
<td>1,775</td>
<td>15,933</td>
<td>17,708</td>
<td>78,779</td>
</tr>
<tr>
<td>1st trimester</td>
<td>1,339</td>
<td>68.4</td>
<td>10,988</td>
<td>66.3</td>
</tr>
<tr>
<td>2nd trimester</td>
<td>394</td>
<td>20.1</td>
<td>3,607</td>
<td>21.8</td>
</tr>
<tr>
<td>3rd trimester</td>
<td>95</td>
<td>4.9</td>
<td>879</td>
<td>5.3</td>
</tr>
<tr>
<td>No Prenatal care</td>
<td>129</td>
<td>6.6</td>
<td>1,101</td>
<td>6.6</td>
</tr>
<tr>
<td>Delivery Method(^h)</td>
<td>3,695</td>
<td>30,452</td>
<td>34,147</td>
<td>152,300</td>
</tr>
<tr>
<td>Vaginal</td>
<td>2,063</td>
<td>55.8</td>
<td>18,785</td>
<td>61.7</td>
</tr>
<tr>
<td>C-section</td>
<td>1,632</td>
<td>44.2</td>
<td>11,667</td>
<td>38.3</td>
</tr>
<tr>
<td>Morbidity</td>
<td>3,763</td>
<td>30,926</td>
<td>34,689</td>
<td>151,711</td>
</tr>
<tr>
<td>Diabetes</td>
<td>320</td>
<td>8.5</td>
<td>2,115</td>
<td>6.8</td>
</tr>
<tr>
<td>Hypertension(^i)</td>
<td>307</td>
<td>8.2</td>
<td>2,530</td>
<td>8.2</td>
</tr>
<tr>
<td>Smoke During Pregnancy(^j)</td>
<td>1,988</td>
<td>17,165</td>
<td>19,153</td>
<td>1,262</td>
</tr>
<tr>
<td>Yes</td>
<td>62</td>
<td>3.1</td>
<td>1,200</td>
<td>7.0</td>
</tr>
</tbody>
</table>

\(^a\) Counties 100 Km north of the U.S.-Mexico international line in Arizona, California, New Mexico, and Texas.
\(^b\) Non-border counties in the four border states of Arizona, California, New Mexico, and Texas.
\(^c\) The four U.S.-Mexico border states of Arizona, California, New Mexico, and Texas.
\(^d\) Includes only fetal and infant deaths of U.S. resident mothers.
\(^e\) Not available in Fetal deaths. Therefore, only includes infants.
\(^f\) Education questions differ in the 1989 and 2003 versions of the birth certificate. The variable in both version was combined to create the categories.
\(^g\) Prenatal care questions differed in the 1989 and 2003 versions of the birth certificate. The variable in both versions were combined to create the categories.
\(^h\) Includes chronic hypertension, pregnancy associated hypertension, and eclampsia
\(^i\) Smoking during pregnancy questions differed in the 1989 and 2003 versions of the birth certificate. The variables in both version were combined to create the categories.
3.2.1 Feto-infant death rates 2009 – 2013 in border states as compared to U.S., and in border counties as compared to non-border counties in border states

The border states had a lower feto-infant death rate as compared to the U.S., 6.9 per 1,000 live and fetal deaths and 7.8 per 1,000, respectively (Table 7). Both, the border states and the U.S. had the highest rate of excess deaths in the MHP category (0.7 per 1,000 and 1.0 per 1,000), the second highest excess death rates in the IH category (0.3 per 1,000 and 0.5 per 1,000). In the border states, 48% of the excess deaths were attributed to the MHP and 24% to the IH category. While in the U.S. 46% of the excess deaths were attributed to the MHP period and 24% to IH.

When comparing the counties in the border states, border counties had a lower feto-infant mortality rate, 6.3 per 1,000 as compared to the non-border counties, 6.9 per 1,000. In both, the border and non-border counties the MHP category had the highest excess death rates (0.4 per 1,000 and 0.7 per 1,000), followed by the IH category (0.2 per 1,000 and 0.3 per 1,000). In the border counties, 52% of the excess deaths were attributed to MHP, and 23% to IH. The non-border counties had a slightly lower percentage of excess death attributed to MHP, 48%, and 24% attributed to IH.

In summary, the excess deaths in all the regions studied were attributed to the MHP and the border counties had the highest percentage (52%) of excess death attributed to the MHP period of risk. Also, in all the four regions studied, IH was the second highest period that contributed to the excess deaths.
Table 7: Perinatal Period of Risk Analysis of Feto-Infant Deaths by Geography from 2009-2013.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Maternal Health/ Prematurity (MHP)</th>
<th>Maternal Care (MC)</th>
<th>Newborn Care (NC)</th>
<th>Infant Health (IH)</th>
<th>Total Feto-Infant Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>External reference group&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of deaths</td>
<td>1048</td>
<td>843</td>
<td>492</td>
<td>585</td>
<td>2,968</td>
</tr>
<tr>
<td>Death rate per 1,000 live births and fetal deaths</td>
<td>2.0</td>
<td>1.6</td>
<td>0.9</td>
<td>1.1</td>
<td>5.5</td>
</tr>
<tr>
<td>U.S.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of deaths</td>
<td>59,525</td>
<td>39,943</td>
<td>23,407</td>
<td>32,690</td>
<td>155,565</td>
</tr>
<tr>
<td>Death rate per 1,000 live births and fetal deaths</td>
<td>3.0</td>
<td>2.0</td>
<td>1.2</td>
<td>1.6</td>
<td>7.8</td>
</tr>
<tr>
<td>Excess death rate&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.0</td>
<td>0.4</td>
<td>0.3</td>
<td>0.5</td>
<td>2.2</td>
</tr>
<tr>
<td>Excess number of deaths&lt;sup&gt;c&lt;/sup&gt;</td>
<td>20,445</td>
<td>8,507</td>
<td>5,060</td>
<td>10,875</td>
<td>44,888</td>
</tr>
<tr>
<td>Percent contribution of excess deaths&lt;sup&gt;d&lt;/sup&gt;</td>
<td>46%</td>
<td>19%</td>
<td>11%</td>
<td>24%</td>
<td>100%</td>
</tr>
<tr>
<td>Border States</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of deaths</td>
<td>13,207</td>
<td>8,966</td>
<td>5,537</td>
<td>7,163</td>
<td>34,873</td>
</tr>
<tr>
<td>Death rate per 1,000 live births and fetal deaths</td>
<td>2.6</td>
<td>1.8</td>
<td>1.1</td>
<td>1.4</td>
<td>6.9</td>
</tr>
<tr>
<td>Excess death rate&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.7</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Excess number of deaths&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3,322</td>
<td>1,015</td>
<td>896</td>
<td>1,645</td>
<td>6,878</td>
</tr>
<tr>
<td>Percent contribution of excess deaths&lt;sup&gt;d&lt;/sup&gt;</td>
<td>48%</td>
<td>15%</td>
<td>13%</td>
<td>24%</td>
<td>100%</td>
</tr>
<tr>
<td>Border Counties in the Border States</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of deaths</td>
<td>1,410</td>
<td>997</td>
<td>610</td>
<td>762</td>
<td>3,779</td>
</tr>
<tr>
<td>Death rate per 1,000 live births and fetal deaths</td>
<td>2.4</td>
<td>1.7</td>
<td>1.1</td>
<td>1.3</td>
<td>6.3</td>
</tr>
<tr>
<td>Excess death rate&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.4</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Excess number of deaths&lt;sup&gt;c&lt;/sup&gt;</td>
<td>238</td>
<td>54</td>
<td>60</td>
<td>108</td>
<td>460</td>
</tr>
<tr>
<td>Percent contribution of excess deaths&lt;sup&gt;d&lt;/sup&gt;</td>
<td>52%</td>
<td>12%</td>
<td>13%</td>
<td>23%</td>
<td>100%</td>
</tr>
<tr>
<td>Non-Border Counties in the Border States</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of deaths</td>
<td>11,797</td>
<td>7,969</td>
<td>4,927</td>
<td>6,401</td>
<td>31,094</td>
</tr>
<tr>
<td>Death rate per 1,000 live births and fetal deaths</td>
<td>2.6</td>
<td>1.8</td>
<td>1.1</td>
<td>1.4</td>
<td>7.0</td>
</tr>
<tr>
<td>Excess death rate&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.7</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Excess number of deaths&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3,084</td>
<td>960</td>
<td>837</td>
<td>1,537</td>
<td>6,418</td>
</tr>
<tr>
<td>Percent contribution of excess deaths&lt;sup&gt;d&lt;/sup&gt;</td>
<td>48%</td>
<td>15%</td>
<td>13%</td>
<td>24%</td>
<td>100%</td>
</tr>
</tbody>
</table>

<sup>a</sup>Feto-infant death rate for non-Hispanic White women aged 20-34 years residing in California.

<sup>b</sup>Death rate for category minus death rate for reference group category.

<sup>c</sup>Excess death rate times total number of live births and fetal deaths divided by 1,000.

<sup>d</sup>Excess deaths per category divided by total excess deaths.
Table 8: Perinatal Period of Risk Analysis of Feto-Infant Deaths by Border State from 2009-2013.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Maternal Health/ Prematurity (MHP)</th>
<th>Maternal Care (MC)</th>
<th>Newborn Care (NC)</th>
<th>Infant Health (IH)</th>
<th>Total Feto-Infant Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External reference group</strong>^a^</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of deaths</td>
<td>1,048</td>
<td>843</td>
<td>492</td>
<td>585</td>
<td>2,968</td>
</tr>
<tr>
<td>Death rate per 1,000 live births and fetal deaths</td>
<td>2.0</td>
<td>1.6</td>
<td>0.9</td>
<td>1.1</td>
<td>5.5</td>
</tr>
<tr>
<td><strong>Arizona</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of deaths</td>
<td>1,152</td>
<td>870</td>
<td>543</td>
<td>718</td>
<td>3,283</td>
</tr>
<tr>
<td>Death rate per 1,000 live births and fetal deaths</td>
<td>2.6</td>
<td>2.0</td>
<td>1.2</td>
<td>1.6</td>
<td>7.5</td>
</tr>
<tr>
<td>Excess death rate^b^</td>
<td>0.7</td>
<td>0.4</td>
<td>0.3</td>
<td>0.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Excess number of deaths^c^</td>
<td>294</td>
<td>180</td>
<td>140</td>
<td>239</td>
<td>853</td>
</tr>
<tr>
<td>Percent contribution of excess deaths^d^</td>
<td>34%</td>
<td>21%</td>
<td>16%</td>
<td>28%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>California</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of deaths</td>
<td>6,513</td>
<td>4,588</td>
<td>2,590</td>
<td>2,950</td>
<td>16,641</td>
</tr>
<tr>
<td>Death rate per 1,000 live births and fetal deaths</td>
<td>2.6</td>
<td>1.8</td>
<td>1.0</td>
<td>1.2</td>
<td>6.6</td>
</tr>
<tr>
<td>Excess death rate^b^</td>
<td>0.6</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Excess number of deaths^c^</td>
<td>1,545</td>
<td>592</td>
<td>258</td>
<td>177</td>
<td>2,571</td>
</tr>
<tr>
<td>Percent contribution of excess deaths^d^</td>
<td>60%</td>
<td>23%</td>
<td>10%</td>
<td>7%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>New Mexico</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of deaths</td>
<td>471</td>
<td>234</td>
<td>178</td>
<td>204</td>
<td>1,087</td>
</tr>
<tr>
<td>Death rate per 1,000 live births and fetal deaths</td>
<td>3.4</td>
<td>1.7</td>
<td>1.3</td>
<td>1.5</td>
<td>7.9</td>
</tr>
<tr>
<td>Excess death rate^b^</td>
<td>1.5</td>
<td>0.1</td>
<td>0.4</td>
<td>0.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Excess number of deaths^c^</td>
<td>202</td>
<td>17</td>
<td>51</td>
<td>54</td>
<td>324</td>
</tr>
<tr>
<td>Percent contribution of excess deaths^d^</td>
<td>62%</td>
<td>5%</td>
<td>16%</td>
<td>17%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Texas</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of deaths</td>
<td>5,202</td>
<td>3,273</td>
<td>2,226</td>
<td>3,291</td>
<td>13,992</td>
</tr>
<tr>
<td>Death rate per 1,000 live births and fetal deaths</td>
<td>2.7</td>
<td>1.7</td>
<td>1.1</td>
<td>1.7</td>
<td>7.2</td>
</tr>
<tr>
<td>Excess death rate^b^</td>
<td>0.7</td>
<td>0.1</td>
<td>0.2</td>
<td>0.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Excess number of deaths^c^</td>
<td>1,412</td>
<td>224</td>
<td>447</td>
<td>1,125</td>
<td>3,259</td>
</tr>
<tr>
<td>Percent contribution of excess deaths^d^</td>
<td>43%</td>
<td>7%</td>
<td>14%</td>
<td>36%</td>
<td>100%</td>
</tr>
</tbody>
</table>

^a Feto-infant death rate for non-Hispanic White women aged 20-34 years residing in California.

^b Death rate for category minus death rate for reference group category.

^c Excess death rate times total number of live births and fetal deaths divided by 1,000.

^d Excess deaths per category divided by total excess deaths.
3.2.2 Feto-infant death rates 2009 – 2013 in the border states of Arizona, California, New Mexico, and Texas

Of the four border states, California had the lowest feto-infant mortality rate, 6.6 per 1,000 live births and fetal deaths, and New Mexico had the highest rates, 7.9 per 1,000 (Table 8). The border states had more variability in which period of risk contributed the most to the excess deaths. In Arizona, most of the excess deaths were credited to the MHP (34%) and the IH (28%) which mirrors what was seen in the border states, border counties and non-border counties. Likewise, in Texas, most of the excess deaths occurred in MHP (43%) and IH (36%). However, in California, the majority of the excess deaths occurred in MHP (60%) and MC (23%). Also, in New Mexico, most of the excess deaths were in the MHP risk period (62%), but the IH (17%) and NC (16%) were the closely tied for the second biggest contributors of the excess deaths.

3.3 PPOR Phase II Results

3.3.1 Low birthweight and very low birthweight in the border counties

The Kitagawa formula was used to determine the risk factors associated with low birthweight in the region, since approximately half (52%), of the excess deaths, were attributed to the MHP period in the border counties. Table 9 shows the birthweight distribution and birthweight-specific mortality for the border counties (target population) and the reference group. The border counties had higher percentages of its live births and fetal deaths among all of the low birthweight categories (< 2,500 grams is low birth weight) as compared to the reference group (Table 9). Also, the feto-infant mortality rates were lower for the border population in the 500-749, 750-999, 1000-1,249, and 2000-2499 grams birthweight groups which showed a survival advantage among the border counties population as compared to the reference group in these categories. There was not a pronounced survival advantage for normal weight babies (2,500+ grams) in the reference group as compared to the border counties since the infant mortality was similar in this group, 2.5 and 2.6 respectively.
Table 9: Excess Mortality Effects on Birthweight Distribution and Birthweight-Specific Mortality, 2009-2013

<table>
<thead>
<tr>
<th>Birthweight</th>
<th>Target Population= U.S.-Mexico Border Population</th>
<th>Reference Population¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Live Births and Fetal Deaths</td>
<td>Number of Feto-infant Deaths</td>
</tr>
<tr>
<td>500-749</td>
<td>1,375</td>
<td>693</td>
</tr>
<tr>
<td>750-999</td>
<td>1,539</td>
<td>315</td>
</tr>
<tr>
<td>1,000-1,249</td>
<td>1,771</td>
<td>223</td>
</tr>
<tr>
<td>1,250-1,499</td>
<td>2,165</td>
<td>215</td>
</tr>
<tr>
<td>1,500-1,999</td>
<td>8,708</td>
<td>431</td>
</tr>
<tr>
<td>2,000-2,499</td>
<td>28,836</td>
<td>489</td>
</tr>
<tr>
<td>2,500-6,499</td>
<td>555,023</td>
<td>1,464</td>
</tr>
<tr>
<td>Total</td>
<td>599,417</td>
<td>3,830</td>
</tr>
</tbody>
</table>

¹ Non-Hispanic white mothers, 20-34 years old, residing in California.

Table 10 shows the contribution of both pathways to the excess feto-infant mortality rate. The total contribution for the birthweight-specific mortality is negative, which may indicate that the target population had a survival advantage over the reference population. A reason may be that prematurity in the reference population was more often associated with some other mortality-related condition (e.g., congenital anomalies). However, the rate of live births and fetal deaths of 500-749g birthweight contributed 41.1% to the overall excess death rate of 0.79. In addition, the overall contribution of VLBW to the rate is 78.9% (0.40). Therefore, the pathway associated with low birthweight and prematurity deaths in the border region were related to birthweight distribution. Behavioral, economic, and health risk factors can influence deaths due to birthweight distribution. The risk factors associated with this pathway that are available in the data set include prenatal care, previous preterm birth, insurance type, education, and smoking during pregnancy.
Table 10. Percentage contribution of the difference in feto-infant mortality rates by Kitagawa Analysis, U.S.-Mexico Border Counties, 2009-2013

<table>
<thead>
<tr>
<th>Birthweight</th>
<th>Actual Contribution to the Difference in Excess Mortality Rates</th>
<th>Percentage Contribution to the Difference in Excess Mortality Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Birthweight Distribution</td>
<td>Feto-infant Birthweight Specific Mortality</td>
</tr>
<tr>
<td>500-749</td>
<td>0.33</td>
<td>-0.14</td>
</tr>
<tr>
<td>750-999</td>
<td>0.15</td>
<td>-0.08</td>
</tr>
<tr>
<td>1,000-1,249</td>
<td>0.09</td>
<td>-0.02</td>
</tr>
<tr>
<td>1,250-1,499</td>
<td>0.07</td>
<td>0.01</td>
</tr>
<tr>
<td>1,500-1,999</td>
<td>0.15</td>
<td>0.01</td>
</tr>
<tr>
<td>2,000-2,499</td>
<td>0.22</td>
<td>-0.07</td>
</tr>
<tr>
<td>2,500-6,499</td>
<td>-0.05</td>
<td>0.13</td>
</tr>
<tr>
<td>Total: 500-6,499</td>
<td>0.95</td>
<td>-0.16</td>
</tr>
<tr>
<td>VLBW Total:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1,499</td>
<td>0.63</td>
<td>-0.23</td>
</tr>
</tbody>
</table>

3.3.2 Risk factors associated with infant deaths in the MHP period of risk

Risk factors for infant death were studied further to characterize the leading causes of death in the border region. When MHP was the period with the highest excess deaths and most of the deaths were due to very low birthweight (VLBW), the causes of death information were not used to determine the leading cause of death. This is because causes of death for fetal deaths were not well reported and the cause of death for infants that are VLBW are generally multifactorial, inconsistently reported and unreliable since multiple hospitals and physicians can be responsible for reporting (Sappenfield et al., 2010b).

Chi-square was used to analyze possible differences in risk factors of border counties as compared to the reference group, and Table 11 shows the prevalence of risk factors associated with VLBW in the border population and reference population. In the border counties, smoking during pregnancy was more prevalent among mothers of infants born VLBW compared to not VLBW. However, smoking during pregnancy only had a PAR% or 0.69%. Thus, of the VLBW
births in the border counties, only 0.69% can be attributed to smoking. In contrast, in the reference population, a mother having a previous preterm birth, paying with Medicaid, having less than 13 years of education, and smoking during pregnancy were more prevalent among infants born VLBW compared to not VLBW. Also, in the reference population, the PAR% among VLBW births was 3.1% for previous preterm birth, 5.4% for paying with Medicaid, 4.4% for having less than 13 years of education, and 2.4% smoking during pregnancy.

Table 11: Prevalence and Population Attributable Risk Percent (PAR %) of Risk factors Associated with Having a Very Low Birthweight (VLBW) Infant among Border County Women and Reference Group, 2009-2013

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Border Counties VLBW Births (N=508,851)</th>
<th>Reference Groupa VLBW Births (N=534,326)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Prenatal Care Initiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late or no careb</td>
<td>480</td>
<td>1.1</td>
</tr>
<tr>
<td>Timelyc</td>
<td>4769</td>
<td>1.0</td>
</tr>
<tr>
<td>Previous Preterm Birth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>167</td>
<td>3.1</td>
</tr>
<tr>
<td>No</td>
<td>5177</td>
<td>1.0</td>
</tr>
<tr>
<td>Medicaidd</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2443</td>
<td>1.1</td>
</tr>
<tr>
<td>No</td>
<td>2901</td>
<td>1.0</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 13 years</td>
<td>2694</td>
<td>1.1</td>
</tr>
<tr>
<td>≥ 13 years</td>
<td>2349</td>
<td>1.0</td>
</tr>
<tr>
<td>Smoke During pregnancy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>5336</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No</td>
<td>5216</td>
<td>1.0</td>
</tr>
</tbody>
</table>

a Feto-infant death rate for non-Hispanic White women, aged 20-34 years residing in California.
b No prenatal care or initiation during 3rd trimester.
c Prenatal Care initiation during 1st or 2nd trimester.
d Type of insurance used to pay for medical charges for the birth.
Table 12 shows the odds ratios for the risk factors associated with having a VLBW infant. In the border counties, smoking (AOR= 1.4; 95% CL: 1.2-1.7), and previous preterm birth (AOR= 3.0; 95% CL: 2.5-3.5) were associated with having a VLBW baby. Likewise, for the reference population, smoking during pregnancy (AOR= 1.3; 95% CL: 1.1-1.5) and previous pre-term birth (AOR= 4.7; 95% CL: 1.0-5.5) were also associated with having a VLBW infant.

**Table 12: Odds Ratios of Risk Factors Associated with Having a Very Low Birthweight (VLBW) Infant among Border County Women and Reference Group, 2009-2013**

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Border Counties (N=508,851)</th>
<th>Reference Populationa (N=524,005)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crude Odds Ratio 95% CL</td>
<td>Adjusted Odds Ratio 95% CL</td>
</tr>
<tr>
<td>Prenatal Care Initiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late or no careb</td>
<td>1.1 (0.97 -1.2)</td>
<td>1.1 (0.96 -1.2)</td>
</tr>
<tr>
<td>Timelyc</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td>Previous Preterm Birth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>3.0*** (2.6 - 3.6)</td>
<td>3.0*** (2.5 - 3.5)</td>
</tr>
<tr>
<td>No</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td>Medicaidd</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.1* (1.0 - 1.1)</td>
<td>1.0 (0.96 - 1.1)</td>
</tr>
<tr>
<td>No</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 13 years</td>
<td>1.1* (1.0 - 1.1)</td>
<td>1.1 (1.0 - 1.1)</td>
</tr>
<tr>
<td>≥ 13 years</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td>Smoke During Pregnancy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.4*** (1.2 - 1.7)</td>
<td>1.4** (1.1 - 1.7)</td>
</tr>
<tr>
<td>No</td>
<td>Ref</td>
<td>Ref</td>
</tr>
</tbody>
</table>

*p-value < 0.05; **p-value < 0.01; ***p-value <0.001

a Feto-infant death rate for non-Hispanic White women, aged 20-34 years residing in California.
b No prenatal care or initiation during 3rd trimester.
c Prenatal Care initiation during 1st or 2nd trimester.
d Type of insurance used to pay for medical charges for the birth.
3.3.3 Maternal characteristics associated with infant dying in a border state compared to Non-border States

Table 13 shows the maternal factors associated with a feto-infant death in the border state as compared to a non-border state. The maternal risk associated with infant deaths in the border states (Arizona, California, New Mexico, and Texas) and non-border states (the other 46 U.S. states) were studied. Mothers in the border states compared to mothers in non-border states were less likely to smoke during pregnancy (6.6% vs. 19.6%; p-value < 0.001), and have a medical risk (11.3% vs. 12.9%; p-value < 0.001). Also, border state mothers were more likely to be married (p-value < 0.001), have no or late prenatal care (p-value = 0.001) and have < 13 years of education (p-value < 0.001) as compared to mothers that experienced an infant death in a non-border state.

Table 13. Prevalence of Selected Maternal Characteristic for U.S. Mexico Border States Feto-infant Deaths Compared to Non-Border States, 2009-2013

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Border State (N=20,498)</th>
<th>Non-Border State (N=71,784)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Medical Riska</td>
<td>20,497</td>
<td>2,321</td>
<td>11.3</td>
</tr>
<tr>
<td>No or Late prenatal careb</td>
<td>18,532</td>
<td>2,204</td>
<td>11.9</td>
</tr>
<tr>
<td>&lt; 13 years of education</td>
<td>17,757</td>
<td>10,460</td>
<td>58.9</td>
</tr>
<tr>
<td>Married</td>
<td>20,498</td>
<td>10,109</td>
<td>49.3</td>
</tr>
<tr>
<td>Smoking During Pregnancy</td>
<td>19,153</td>
<td>1,262</td>
<td>6.6</td>
</tr>
</tbody>
</table>

a Includes chronic hypertension, pregnancy associated hypertension, and eclampsia.

b No prenatal care or initiation during 3rd trimester.

3.4 SUMMARY OF RESULTS BY SPECIFIC OBJECTIVE, RESEARCH QUESTION, AND HYPOTHESIS

Objective 1: Determine the overall feto-infant mortality rate for the U.S side of the U.S.-Mexico Border Region and compare it to border states and the U.S. national rates.
Research Question 1: What is the overall feto-infant mortality rate for the U.S. side of the U.S.-Mexico Border Region compared to the U.S. and border states rates?

H1: The U.S Mexico border region will have higher feto-Infant mortality rates than the combined border states and the U.S. national rates.

The overall feto-infant death rate in the border counties was 6.3 feto-infant deaths per 1,000 live births and fetal deaths from 2009 to 2013. This rate was lower than the national (7.8 per 1,000), border states (6.9 per 1,000), and the non-border counties (7.0 per 1,000) (Table 7).

Objective 2: Determine if border counties have higher excess feto-infant deaths than non-border counties in the U.S. border states.

Research Question 2: Are there differences in excess feto-infant deaths in border counties compared to non-border counties in the U.S. border states?

H2: The U.S. border counties within the U.S. Border States will have higher excess feto-infant deaths than non-border counties within the U.S. Border States.

The excess feto-infant mortality rate of the border counties in the four border states was 0.8 feto-infant deaths per 1,000 live births and fetal deaths, which equates to 460 preventable deaths from 2009-2013. The non-border counties excess mortality rate was 1.4 per 1,000 which results in 6,418 excess deaths in this time period. The non-border counties excess death rate was the same as the excess death rate for the border states (1.4 per 1,000) (Table 7).

Objective 3: Determine if there are differences in specific periods of risk that show excess feto-infant deaths in border counties as compared to non-border counties in the U.S. border states.

Research Question 3: Are there differences among the specific periods of risk that show excess feto-infant deaths in border counties compared to non-border counties in the U.S. border states?

H3: The U.S. border counties within the U.S. Border States will one or more identifiable periods of risk associated with excess feto-infant deaths.
In the border counties, the highest excess death rate was found in the Maternal Health/Prematurity (MHP) perinatal period (0.4 per 1,000), similar to the non-border counties (MHP= 0.7 per 1,000). However, the MPH in the border counties contributed 52% to the overall excess deaths, and risk factors for this category are associated with adverse birth outcome (low birthweight) in the U.S. Mexico border region.

**Objective 4:** Determine what risk factors are associated with low birthweight and prematurity in the U.S. Mexico border region.

- **Research Question 4:** What risk factors are associated with low birthweight and prematurity in the U.S. Mexico border region?
- **H4:** Maternal morbidity (diabetes and hypertension), maternal education, and maternal behaviors will be significantly associated with adverse birth outcome (low birthweight and preterm).

In the MHP the pathway associated with the feto-infant mortality in the border counties was birthweight distribution, and VLBW had the highest impact in the feto-infant mortality. The risk factors identified that were associated with this pathway and could be studied were prenatal care, previous preterm birth, insurance type, education, and smoking during pregnancy. In the border counties, smoking during pregnancy, when controlling for all other variables, was significantly more prevalent among infants born VLBW as compared to not VLBW.

**Objective 5:** Determine what maternal characteristics are associated with an infant dying in the in the U.S. border states.

- **Research Question 5:** What maternal characteristics are associated with an infant dying in the U.S. border states?
- **H5:** Younger maternal age, low education, and residing in a border county will be associated with a higher risk of infant death in the U.S. border states.

In the border counties smoking (AOR= 1.4; 95% CL: 1.2-1.7), and previous preterm birth (AOR= 3.0; 95% CL: 2.5-3.5) were associated with having a VLBW baby.
Objective 6: Determine what factors are associated with the leading cause of death in the PPOR with the highest excess deaths in the U.S Mexico border region.

- Research Question 6: What factors are associated with the leading cause of death in the PPOR with the highest excess deaths in the U.S. Mexico border region?
- H$_6$: Behavioral factors will be significantly associated with the leading cause of death in the PPOR with the highest excess deaths in the U.S. Mexico border region.

Border mothers that experienced infant death were less likely to have a medical risk and to smoke during pregnancy, and more likely to be married, have no or late prenatal care and have < 13 years of education as compared to mothers that experienced an infant death in a non-border state (Table 13).
Chapter 4: Discussion

The U.S.-Mexico border region covers four states from east to west along the southern U.S. border, including Texas, New Mexico, Arizona and California, and 44 U.S. border counties defined as those lying within 50 miles north of the border. The region is bicultural with approximately 185 million border crossings a year for work, school, tourism, and healthcare among other reasons (U.S.-Mexico Border Health Commission, 2014b). The high volume of border crossings has required local collaboration between the U.S. and Mexico when it comes to public health, security, trade, border management and environmental resources (Lee et al., 2013). This population fluidity has also required collaboration in the public health sector, where public health professionals in the county and states from both countries work together to solve health problems affecting both sides. Thus, the border is a region unlike any other region in the U.S. with its unique bi-national social, cultural, and economic relationships, yet at the same time spanning sovereign states and counties with U.S. laws and regulation. Due to the strong interconnection of cities on either side of the border, health issues and diseases do not stop at one side of the border, making the international borderline blurred, and forcing agencies on both sides of the border to work together to solve health issues, particularly infectious diseases.

Regarding health issues, the border region poses challenges. For example, there is a higher incidence of health and reproductive problems on the U.S. border counties than compared to the U.S. (McDonald et al., 2008; McDonald et al., 2013; Xaverius et al., 2014). At the same time, a larger percentage of residents live near or below the national poverty level and traditionally, financial resources for this region have been and continue to be extremely limited (Health Resources and Services Administration, 2009; U.S.-Mexico Border Health Commission, 2003).

With regards to reproductive health, while initial reports previously suggested that fetal/infant deaths were lower in some border regions (U.S.-Mexico Border Health Commission, 2014b; U.S.-Mexico Border Health Commission, 2003), overall, research on infant mortality in
this region is scarce and outdated and required further study. Moreover, there is a gap in the literature regarding whether specific periods of risks contribute to infant deaths differently in the U.S. non-border states as compared to the border states. Also, the limited data that exists does not look at the U.S. border region as a whole; data tend to be specific to a single state or single county (Mathews et al., 2015; U.S.-Mexico Border Health Commission, 2014b; U.S.-Mexico Border Health Commission, 2003). Since the U.S. border region is recognized as having a population that differs in health problems and social determinants of health, infant mortality of the whole U.S. border region would be useful in evaluating the health of the region.

This study attempted to determine if there were differences in infant mortality and excess death in counties on the U.S. side of the U.S.-Mexico border region, as compared to non-border counties in border states, border states in general, and in the U.S. overall. The results could critically guide community-based inventions with the highest likelihood of reducing infant deaths.

4.1 Descriptive Characteristics of Mothers Experiencing Feto-Infant Deaths

As expected, the descriptive statistics showed that most of the mothers experiencing a feto-infant death in the border counties were Hispanic (56.4%) as compared to the other regions considered, including non-border counties (37.4%), border states (39.5%), and the U.S. (17.3%). This mirrors the ethnic population distribution in the border counties, where Hispanics make up a higher percentage of the population (U.S. Census Bureau, 2010). Also, the fertility rate of women in the border counties has been reported to be higher in the border counties than the non-border counties and the U.S. (McDonald et al., 2013). Thus, the higher percentage of Hispanic women experiencing a feto-infant death in the border counties is likely due to the population distribution and higher fertility rates. Also, in the border counties, a higher percentage of mothers were less than 20 years of age, 13.3%, as compared to the other regions studied (non-border counties = 11.5%, border states= 11.7%, U.S. 11.3%). These findings were consistent with one previous study that showed birth rates among 15 to 19 year-old women in the border counties
were higher than U.S. rates overall (McDonald et al., 2013). Also, published data on adolescent health show that among all border states, except for California, teen birth rates are higher among 15 to 19 year-old females than in the U.S. (U.S. Census Bureau, 2010). Therefore, the slightly higher percentage of women 19 years-old and younger experiencing a fetal/infant death in the border counties might be explained by the higher birth rate among this age group.

With regards to education, more mothers in the border counties had lower education attainment, with 31.5% attaining less than 12 years of education, as compared to the other regions studied (non-border counties= 28.1%; border states= 28.4%; and U.S.= 25.0%). Interestingly, although it has been reported that the border residents overall have lower levels of education than the national average (U.S.-Mexico Border Health Commission, 2003), McDonald et al., found that Hispanic women giving birth in the border counties had higher levels of education attainment as compared to Hispanic mothers in the U.S. and non-border counties (2013). This suggested that Hispanic mothers experiencing a fetal or infant death in the border counties were somehow different from the majority of women giving birth in these counties, or that education could somehow be associated with an increased risk of having a birth resulting in a feto-infant death.

Unexpectedly, a higher proportion of the mothers experiencing a fetal/infant death in the border counties had higher prenatal care initiation in the first-trimester, 68.4%, as compared to the other regions studied (non-border counties = 66.3%, border states= 66.5%, U.S.= 66.7%). Other studies have reported different findings suggesting that late or no prenatal care was more prevalent and first trimester initiation less prevalent among Hispanic women and in the border regions than in the non-border regions in U.S. border states (McDonald et al., 2008; McDonald, Suellentrop, Paulozzi, & Morrow, 2008; McDonald et al., 2013; Selchau et al., 2017).

One explanation, for this difference is that since the mothers in the border counties also tended to have higher rates of diabetes (8.5% vs. non-border counties =6.8% and U.S.= 7.3%), they may already be under care of a doctor or have frequent contact with medical professionals and therefore, are more likely to seek prenatal care.
In the border counties, the percentages of C-sections during delivery were much higher than in the other regions studied (44.2% vs. non-border counties = 38.3%, border states = 38.9%, and U.S. = 37.9%) among mothers experiencing a fetal loss or infant death. Higher proportions of C-sections have been reported in previous studies of birth characteristics in Hispanic in the border counties and the border region (McDonald et al., 2013), as well as in low-risk C-sections in Hispanic and non-Hispanic women in the border states (McDonald, Amatya, Gard, & Sigala, 2018). As mentioned above, since these mothers in the border counties tended to have higher morbidities, such as diabetes, they may have had more pregnancy or labor complications resulting in medically necessary C-sections. No information was available in the data accessed for this study to determine whether C-sections reported were medically necessary or elective.

Based on the descriptive data alone, the border counties had the lowest percent distribution of mothers reporting smoking during pregnancy, 3.1% as compared to the other regions (non-border counties = 7.0%, border states = 5.3%, U.S. = 16.4%). One other previous study had similar results and reported low smoking rates among women giving birth in the border counties (Drake, Driscoll, & Mathews, 2018; McDonald et al., 2013). Various studies have found that smoking during pregnancy is a major contributor to LBW and VLBW infants (Ko et al., 2014; Xaverius et al., 2014). Thus, the low smoking rate could also explain why mothers experiencing a fetal/infant death in the border counties also had slightly heavier infants as compared to the non-border counties (Table 6). Also, this implies that the women in this study may somehow be different from women giving birth in the border region since previous 2009 birth data showed that a higher proportion of Hispanic women had LBW births in the border counties than non-border counties (McDonald et al., 2013). Although a smaller proportion of women experiencing a fetal/infant in the border counties tended to have VLBW infants, this was a significant contributor to the excess deaths occurring in the border counties, as discussed below in the PPOR finding section.

In summary, the demographic characteristics, such as age, ethnicity, and morbidity of women experience a fetal/infant death in the border counties were similar to previous data
reported for women giving birth in the border counties within border states. However, these women may differ in education attainment, and prenatal care initiation from women giving birth in the border region and further research that controls for these factors is needed to see if the differences persist.

4.2 Overview of the findings

There were five major findings of this study:

1. The overall feto-infant death rate in the border counties was lower than the national, border states, and the non-border counties (Section 3.2.1, page 38).

2. The excess feto-infant mortality rate of the border counties within the four border states was lower than the excess feto-infant mortality rate for the non-border counties. Also, the non-border counties excess death rate was the same as the excess death rate for the border states (Section 3.2.1, page 38).

3. In the border counties, the highest excess death rate was found in the Maternal Health/Prematurity (MHP) perinatal period similar to the non-border counties. However, the MPH in the border counties contributed 52% to the overall excess deaths (Section 3.2.1, page 38).

4. In the MHP period of risk, which had the highest excess death rate, the pathway associated with feto-infant death was birthweight distribution, and VLBW babies contributed the most to the feto-infant death rate for the border counties (Section 3.3.1, page 42). Furthermore, in the border counties, smoking during pregnancy and previous pre-term birth were associated with having a VLBW baby after controlling for prenatal care initiation, Medicaid insurance, and education attainment (Section 3.3.2, page 44).

5. Border mothers that experienced a fatal/infant death were less likely to have a medical risk and to smoke during pregnancy, and more likely to be married, have no
or late prenatal care and have < 13 years of education as compared to mothers that experienced an infant death in a non-border state (Section 3.3.3, page 47).

Combined, these findings suggest four major conclusions that are discussed in the sections below (4.3-4.6).

4.3 SPECIFIC MATERNAL CHARACTERISTICS WERE ASSOCIATED WITH INFANT DYING IN BORDER STATES VERSUS NON-BORDER STATES

Chi-square analyses were conducted to determine whether the maternal characteristics observed in the descriptive statistics differed significantly between border states (Arizona, California, New Mexico, and Texas) and non-border state (the other 46 U.S. states). Mothers in border states that experienced a fetal/infant death were significantly less likely to have a medical risk and to smoke during pregnancy, and were more likely to be married, have no or late prenatal care, and have < 13 years of education as compared to mothers that experienced an infant death in a non-border states (Table 13). These results were similar to the differences observed in the descriptive statistics for border states as compared to the U.S. (Section 3.1.1).

Surprisingly, the mothers experiencing a fetal/infant death residing in the border states were less likely to have a medical risk (hypertension or diabetes) compared to mothers in the non-border states. In contrast, data shows that Hispanics living in the border counties and Hispanic mothers giving birth in the border region tend to have higher rates of diabetes and obesity than Hispanics in the non-border regions (McDonald et al., 2013; Pan American Health Organization, 2012b). One explanation could be that mothers experiencing a fetal/infant death may differ in morbidity compared to the general population in the border states. Also, as the descriptive statistic showed, although a higher percentage of mothers having an infant death in the border counties did have diabetes, there was a less proportion of mothers with diabetes in the non-border counties in the border states (Table 6). Further research that controls for cofounders is needed to determine how medical risks may differ between border states and the other 46 states in the U.S.
Mothers experiencing a fetal/infant death in the border states were less likely to smoke (6.6%) as compared to non-border state mother (19.4%). This was similar to the descriptive statistic data that showed that a greater proportion of U.S. mothers experiencing a fetal/infant death smoked compared to mothers in the other regions studied. Previous findings support the notion that Hispanic women and women giving birth in the border have lower rates of smoking during pregnancy (Drake et al., 2018; McDonald et al., 2013). As discussed in the descriptive statistic section, smoking during pregnancy is a major risk factor for LBW and VLBW infants (Ko et al., 2014; Kramer, 1989; Xaverius et al., 2014). Although border state mothers had lower prevalence of smoking may associated with the excess VLBW deaths found in the MHP category for the border region as discuss in the section below. Further studies are needed to determine how smoking is associated with LBW and VLBW infants in border states after controlling for cofounders.

The border states had higher prevalence of married mothers experiencing a fetal/infant death as compared to mothers in the non-border states (49.3% vs. 44.6%). This was similar to the findings in the descriptive statistics, which demonstrates that in border states and border counties a higher percentage of mothers experiencing a fetal/infant death were married (49.7% and 51.6%) as compared to mothers experiencing a fetal/infant death in the U.S. (47.1%). Previous studies have shown that overall, a higher proportion of Hispanic mothers giving births in border counties are married (McDonald et al., 2013). Thus this may explain why mothers were more likely to be married in the border states as compared across to non-border states.

In addition, infant mortality statistics have shown that in the U.S. for all ethnicities, married mothers have lower rates of infant mortality than unmarried mothers (Mathews & Driscoll, 2017). Therefore, being married may also influence the lower feto-infant mortality rate seen in the border states (6.9 per 1,000), compared to the national rate observed, 7.8 per 1,000 (Table 7). Marital status is often an indicator of social and financial resources (Mathews & Driscoll, 2017), and thus the availability of insurance through the husband, or other financial and health advantages that may result in survival of infants born with morbidities that can lead to
death. Further research is needed to explore how marital status is a proxy for financial advantages and affect infant mortality and adverse pregnancy outcomes among women in the border region.

Border state mothers experiencing a fetal/infant death were slightly more likely to have no or late prenatal care (initiated in the third-trimester) than mothers across the U.S (11.9% vs.11.0%) (Table 11). Although the descriptive statistics showed that overall the border counties had a higher proportion of first trimester prenatal care initiation, the border states overall did not differ from the mothers in the U.S. in this regards. However when looking just among mothers that had no prenatal care or initiated prenatal care in the third-trimester, the border states had a higher proportion than the U.S. (Table 6). One reason, for the higher proportion could be that more women in the border states receive prenatal care in Mexico, especially those mothers living in the border counties. Previous data have shown high rates of cross-border utilization of prenatal care services among Hispanic pregnant women in the border region (Selchau et al., 2017) and there is no binational sharing of prenatal care data. Therefore, prenatal care received in Mexico would not be recorded in the birth certificate among the women giving birth in the U.S. but utilizing prenatal care services in Mexico. Late and no prenatal care has been documented in the border region by other studies (McDonald et al., 2008; McDonald et al., 2013).

Parity is another factor that can influence timely prenatal care initiation among Hispanic women giving birth in the border regions. Several studies have found that multiparous women were more likely to initiate first-trimester prenatal care than primiparous women (Herbst, Mercer, Beazley, Meyer, & Carr, 2003; McDonald, Argotsinger, Mojarro, Rochat, & Amatya, 2015; Selchau et al., 2017). Also, late pregnancy recognition and lack of medical insurance can lead to late or no prenatal care (Selchau et al., 2017). Another factor that can influence prenatal initiation is the availability of insurance in a state. Some studies suggest that women residing in Texas were less likely to obtain timely prenatal care, perhaps due to the high rates of uninsured in Texas compared to the other border states (Barnett & Vornovitsky, 2016; McDonald et al.,
No information on parity and insurance status was available to in the data analyzed in this study to determine how these factors contributed to the early prenatal care initiation for women experiencing a fetal/infant death in the border region. Further research is needed to determine if the late or no prenatal care is contributing to the fetal/infant deaths and if the higher percentage of early prenatal care initiation among border counties mothers persists after adjusting for possible cofounders, such as maternal morbidities, access to care, insurance, parity, state of residence, and county of prenatal care services.

Mothers experiencing an infant death in the border states were more likely to have lower education attainment (Table 13), which was similar in the descriptive statistics comparing border states and the national rate of the U.S. Other studies have documented lower education attainment for women giving birth and residing in the border counties (Health Resources and Services Administration, 2009; McDonald et al., 2013). This may suggest that education may be related to health factors that may contribute to adverse pregnancy outcome resulting in a fetal or infant death. Further study is needed to determine if the association still exists after adjusting for confounders related to the outcomes observed in the border states.

In addition, education has been used as a proxy for socioeconomic status which is known to influence health behaviors and access to medical care that can affect pregnancy and birth outcomes (Boarlaider et al., 2013). Previous studies have shown a positive association between less education attainment and late prenatal care initiation, which can contribute to adverse pregnancy outcomes, such as infant mortality (Boerleider, Wiegers, Manniën, Francke, & Devillé, W. L. J. M, 2013; Hessol & Fuentes-Afflick, 2014; Kingston, Heaman, Fell, & Chalmers, 2012; Partridge, Balayla, Holcroft, & Abenhaim, 2012). At the same time, as described below, the majority of border women had an early initiation of prenatal care. Therefore, educational attainment may not be related to late prenatal care in these women. Further research is needed to explore how educational attainment may influence feto-infant mortality in border county mothers. In this current study, education was explored further and is discussed below.
4.4 FETO-INFANT MORTALITY RATES WERE LOWER IN BORDER COUNTIES

PPOR Phase I analysis was used to calculate the feto-infant mortality rates for the border counties within border states, non-border counties within border states, border states, and the U.S. For the years 2009-2013, the border counties as compared to border states and the U.S. had a lower feto-infant mortality rate (6.3 per 1,000 as compared to 7.0 per 1,000 for border states and 7.8 per 1,000 for U.S.). These findings were consistent with older studies. While there are not recent reports of feto-infant death rates for the whole region, 2005-2007 data showed that infant mortality was lower (5.5 per 1,000) in the border counties as compared to the border states (5.8 per 1,000) and as compared to the U.S. (6.8 per 1,000) (March of Dimes Perinatal Data Center, 2011). Also, previously, data have shown that U.S. Hispanics have lower infant mortality rates than other racial and ethnic groups (Mathews et al., 2015). Considering the large proportion of Hispanic women residing in the border region, the lower rate could be related to the race and ethnic composition of the border.

One explanation previously offered for the lower feto-infant mortality rates seen in border counties as compared to border states and the U.S. population is often referred to as the “epidemiological paradox” or “Hispanic Paradox” which is seen among Hispanics, especially women of Mexican descent (Hessol & Fuentes-Afflick, 2014; Leonard, Crespi, Gee, Zhu, & Whaley, 2015; Mathews et al., 2015; Rossen & Schoendorf, 2014). The paradox refers to the pattern seen that Hispanic women tend to have better or similar birth outcomes as compared to non-Hispanic Whites despite disparities in sociodemographic factors, such as lower social economic status, education, and lack of insurance (Hessol & Fuentes-Afflick, 2014; Leonard et al., 2015; Rossen & Schoendorf, 2014). This phenomenon was noticed as early as the 1970s, with studies noting the advantage, but the paradox was not named until 1986 by a study noting low infant mortality rates among Hispanics in the southwest (among other health advantages) despite low SES (Markides & Coreil, 1986).

Although the mechanism of the paradox is debated, some studies have found that the length of time in the U.S. and acculturation may influence the epidemiological paradox
(Acevedo-Garcia, Soobader, & Berkman, 2005; Acevedo-Garcia, Soobader, & Berkman, 2007; Hessol & Fuentes-Afflick, 2014). A study looking at 2003 U.S. natality data to study migration and pregnancy outcomes among Mexican Origin women found that Mexican women that lived and resided in Mexico had the lowest risk of delivering preterm or low birth weight infants (contributors to infant mortality), followed by Mexican origin women residing in the U.S. as compared to U.S born Mexican women residing in the U.S. (Hessol & Fuentes-Afflick, 2014).

At the same time, other studies have reported conflicting results, thus the paradox seen is an artifact of record system used to analyze the data, or is attenuated with acculturation in the U.S. or length of stay (Palloni & Arias, 2004; Schaaf, Liem, Mol, Abu-Hanna, & Ravelli, 2013). Further research is needed to determine what role does race/ethnicity, and birth origin of mothers experiencing a feto-infant death have in affecting the mortality rate of the border counties. In addition, to better understand the factors influencing infant-mortality rates observed in the border counties based on the PPOR analysis, the contribution of excess deaths in the four perinatal periods of risk should be studied further.

4.5 Excess Deaths were highest in the MHP category in all border regions

In the PPOR Phase I analysis, the feto-infant mortality rate was compared to the feto-infant mortality rate of the reference group (20-34 years of age non-Hispanic white mothers residing in California) to determine which periods of risks had the highest excess deaths for the border counties and non-border counties within border states, the border states combined, and for each border state individually. In all the regions studied, the Maternal Health and Prematurity (MHP) category contributed the most to the excess deaths. The MHP contributed in the border counties 52%, in non-border counties 48%, and in border states 48% to the excess deaths seen in each region. Similarly, in each of the border states, the largest proportion of the excess deaths were in the MPH category (Arizona = 34%, California = 60%, New Mexico = 62%, and Texas = 46%).
At the time of this study, Texas, Arizona, and Ventura County in California were the only places in the border region known to have conducted a PPOR analysis (Chao et al., 2010; Herrera & Hussaini, June 2014; Texas Department of State Health Services, 2011a; Texas Department of State Health Services, 2011b). These regions showed similar results, with the MPH category having the highest proportion of excess deaths.

In Texas, a 2010 PPOR analysis showed that among Hispanics, 56.1% of excess deaths were in the MHP category and the deaths were mostly attributed to a higher mortality rate among babies being born at very low birthweight (VLBW). Furthermore, the risk factors associated with VLBW deaths in Texas included the mothers gaining less than 15 lbs. of weight during pregnancy; no first-trimester prenatal care initiation; receiving inadequate prenatal care; and teen pregnancy (Texas Department of State Health Services, 2011b). Similarly, the border county of El Paso in Texas showed that 54.6% of its excess deaths occurred in the MHP risk period and the majority of these excess deaths were due to a larger number of VLBW births to teens and Hispanic ethnicity mothers (Texas Department of State Health Services, 2011a). Thus, among the VLBW babies of Hispanic and teen mothers in Texas, the excess deaths were due more to birth weight distribution than just higher mortality rate among VLBW babies. In El Paso the risk factors associated with a baby being born VLBW included the mother gaining less than 15 lbs. of weight during pregnancy, high parity, receiving inadequate prenatal care, and birth defects (Texas Department of State Health Services, 2011a).

Arizona’s Phase I PPOR analysis included data from 2009-2012 and showed that 33% of excess deaths for the state were attributed to the Maternal Care (MC) period of risk, followed by equally attributed to the MHP (32%) and Newborn Care (NC) (32%) categories. However when comparing border and non-border counties within Arizona, in border counties 49% of the excess deaths were attributed to the MHP period, and in non-border counties, 34% were attributed to the MC period (Herrera & Hussaini, June 2014). Similarly, the findings in this study show that most of the excess deaths in Arizona were attributed to the MHP category (34%) (Table 7) and within the state, both the border and non-border counties most of the excess deaths were attributed to
the MHP category, 47% and 31% respectively (data not shown). The differences observed in this study for Arizona may be due to different data years, and reference population used. However, the previous findings along with the findings of this study support that at least for the border counties in Arizona the risk factors associated with the MHP category may contribute to excess deaths similar to Texas and El Paso.

Similarly, the PPOR analysis of the Antelope Valley, a section of Los Angeles in Ventura County, California, reported similar results. The Antelope Valley has a low-income population composed of 14% African Americans, 31% Hispanics/Latinos, and 48% whites. Chao et al. found that the majority of excess deaths (75%) were attributed to the MPH category, mostly among VLBW and LBW infants in the Antelope Valley. Moreover, the risk factors associated with the excess death included the mother having a previous fetal loss, a previous preterm or LBW baby, inadequate prenatal care, and comorbidities before pregnancy like hypertension or obesity (2010).

In summary, these previous studies suggested that the MHP period of risk has the most impact on excess deaths and the feto-infant mortality rate in the border states and counties. Also, that previous adverse pregnancy outcomes (like a fetal loss, and VLBW/LBW infants), timing and adequacy of prenatal care, maternal morbidity, parity, teen pregnancy, and pregnancy gain weight are risk factors that may contribute to excess infant deaths across the border states. As discussed in the next section, the excess deaths in the MPH category, seen in this study, were mostly due to more infants being born as VLBW, similar to the findings of these previous analyses in Texas, El Paso, and Ventura.

Since most of the excess deaths in the border counties and border states occur in the MHP category, it implies that maternal health factors in preconception health, interconnection health, and health behaviors are contributing to the adverse pregnancy outcomes that may result in a fetal or infant death.

A preconception health factor that may explain the high excess deaths in the MHP category in the border region is unintended pregnancies. Previous data from 2010 show that the
border states have high rates of unintended pregnancies (Kost, 2015; Selchau et al., 2017) and if a woman is unaware she is pregnant until after the first trimester it can result in late or no prenatal care initiation (Ayoola, Nettleman, Stommel, & Canady, 2010; Selchau et al., 2017). As mentioned before, late or no prenatal care is known to be associated with adverse pregnancy outcomes, such as LBW, VLBW, and prematurity (Herbst et al., 2003; Hessol & Fuentes-Afflick, 2014; Nodine & Hastings-Tolsma, 2012).

Another preconception health factor that may contribute to the excess deaths in the MHP category is pre-pregnancy morbidity among women in the border regions. It is well documented that obesity increases the risks of pregnancy complications for the mother such as gestational diabetes and preeclampsia which in turn can lead to morbidity and mortality of the fetus/infant. Also, BMI above average (> 24.9) has been associated with large birthweight for the baby, intrauterine death, neural tube defects, fetal death, and prematurity (Centers for Disease Control and Prevention, 2018b; Nodine & Hastings-Tolsma, 2012; Scott-Pillai, Spence, Cardwell, Hunter, & Holmes, 2013; Thanoon, Gharaibeh, & Mahmood, 2015). In a recent study, women with pre-existing diabetes and early gestational diabetes were more likely to have a baby that suffered from prematurity, neonatal jaundice, macrosomia, or had higher rates of admission to neonatal intensive care (Centers for Disease Control and Prevention, 2018b; Sweeting et al., 2016)

Additionally, it is documented that women in the border states have a high prevalence of overweight/obesity and diabetes. Data from 2012 showed that among women living in the four border states the prevalence ranged from 28.2% to 29.9% for being overweight, 23.8% to 30% for obesity, and 9.3% to 10.3% for diabetes (Centers for Disease Control and Prevention, 2015).

Similarly, the descriptive statistic in this study showed that more women in the border counties had diabetes compared to other regions (Table 6). The birth and deaths datasets used in this study did not have maternal weight and height information to assess BMI. Further research is needed to determine to what extent pre-pregnancy health contribute to adverse birth outcomes resulting in fetal/infant death among women in the border region.
One factor to consider may concern statistical artifact. In working with potentially impoverished populations, and also populations including those who may or may not be documented U.S. citizens, the individuals who are counted in national statistics may or may not be representative of those who are not counted. To understand this, it is helpful to think through the origin of the statistics used for these studies. All U.S. states link their birth and death certificates of infants less than one year of age per the guidance of the NCHS, and then the data is transmitted to NCHS for further data cleaning. The linked birth-death data is used for state and national surveillance of maternal and infant health indicators, such as low birthweight rates and infant mortality rates (National Center for Health Statistics, 2000; National Center for Health Statistics, 2016b). While U.S. states share vital statistic data based on the mother’s state of residence, Mexico and the U.S. do not share any vital statistic data. In addition, studies have shown that the border population and pregnant women on the border may utilize health services in both countries or may reside in the U.S. but seek medical care in Mexico (Byrd & Law, 2009; Lapeyrouse et al., 2012; Selchau et al., 2017). Therefore, prenatal care visits may be underreported among immigrants in the border region because of incomplete medical records, language difficulties, and lack of confidence in self-reports of women by hospitals staff completing the birth certificate information (McDonald et al., 2015; Selchau et al., 2017). Also, infant deaths may be underreported, since there would not be a U.S. death certificate to match if a U.S. born infant dies in Mexico.

Additionally, data collection quality depends on the state. Few studies that have looked at the reliability and validity of the 2003 standard birth certificates in the four U.S states of U.S.-Mexico Border Region. The limited literature suggests that the border states continue to have inconsistencies with items on their 2003 standard birth certificate. A study by Andrade et al. evaluated the validity of administrative and claims data from 11 U.S. health plans, and corresponding birth certificate data from state health departments. Three of the health plans accessed were from New Mexico, Northern California, and Southern California. The researchers found considerable agreement (PPVs > 90%) between the birth certificate and medical record
data for measures related to birth weight, gestational age, prior obstetrical history, and race/ethnicity. Also, the PVVs for cardiac defects were 71%, for anencephaly were 37%, for preterm birth were 87%, and 92% for NICU admission (Andrade et al., 2013). Therefore, they found that health plans and birth certificate data had evidence of reliability for some infant outcomes, maternal diagnoses, and newborn, maternal, and paternal characteristics but not for other outcomes and variables.

A great deal of more research is needed in the border region to determine the extent to which flawed reporting practices may be contributing to apparent “benefits” of being Hispanic and/or living on the border. Rather than relying solely on national databases, confirmatory studies conducted in local community clinics and communities by culturally-appropriate healthcare workers such as Promotores, are needed.

The Promotores model includes using members of a targeted community to provide culturally and linguistically appropriate services such as health advocates, navigators, and educators (Capitman, Gonzalez, Ramirez, & Pacheco, n.d.; Centers for Disease Control and Prevention, 2018a; Office of Minority Health, 2016). This model has work in hard-to-reach populations that are uninsured and medically underserve groups by having the Promotores serve as a bridge between the communities and health organizations. Several studies have shown the Promotores Model effective in targeting Hispanic women to reduce hypertension and increase physical activity (Ayala, 2011), increase Folic acid use and awareness of birth defects with low folic acid use (deRosset, Mullenix, Flores, Mattia-Dewey, & Mai, 2014; Prue, Hamner, & Flores, 2010), increase duration of exclusive breastfeeding (Efrat, Esparza, Mendelson, & Lane, 2015; Luna & Badr, 2018), and cervical cancer screening practices knowledge (Fleming et al., 2018; Luque et al., 2017). Promotores could be used in the border region to help mothers that may not speak English accurately complete the mother provided information in the birth certificates to reduce the amount of incorrect information recorded in birth certificates. Also, Promotores can guide pregnant women to seek adequate prenatal care services whether it is in the U.S. or Mexico, and aid in documenting prenatal care services in Mexico that can be used in U.S. Birth
certificates. In addition, *Promotores* could be used for interventions during the pregnancy, such as educating and facilitating prenatal care access. Further research is needed to determine what is the magnitude of infants that are born in the U.S. but die in Mexico and what risk factors are associated with those deaths.

### 4.6 Excess Deaths Were Associated with Very Low Birth Weight Infants

The Kitagawa formula in the PPOR Phase II analysis was used to study further the excess deaths in the MHP category in the border counties since most of the deaths in this period of risk were associated with very low birthweight and prematurity. The majority of the excess deaths were associated with birthweight distribution among VLBW infants (Table 10). This implies that infants were dying because a disproportionally large number were born VLBW.

The current data on differences among women having low birthweight and preterm infants in the border and border counties are mixed. Previous data from 2007 show that both the border counties and border states had similar rates in preterm births (12.5% vs. 12%) and low birthweight (7.4% vs. 7.5%) which are significant contributors to infant mortality (March of Dimes Perinatal Data Center, 2011). However, Hispanic women in the border counties were more likely to have LBW infants than non-Hispanic whites women (7.3% vs. 6.6%) (March of Dimes Perinatal Data Center, 2011). Also, Hispanics women were more likely to have a preterm delivery (a primary cause of VLBW) in the border (12.9% vs. 10.4%), border states (12.0% vs. 11.2%) and the U.S. (2.2% vs. 11.4%) (March of Dimes Perinatal Data Center, 2011). Another study comparing Hispanic women giving births in the border region and the U.S. found similar finding of higher preterm deliveries and low birthweight births among woman in the border counties compared to non-border counties (McDonald et al., 2013). Therefore, in addressing excess deaths in the MHP risk period in the border counties, particular attention should be directed in reducing the percentage of infants born of VLBW.
4.6.1 Risk factors associated with having a very low birthweight birth in the border counties

To further study the risk factors associated with having or not having a VLBW birth in the border region, crude and adjusted logistic regression models were conducted among births in the border counties. Smoking during pregnancy and having a previous preterm birth were risk factors found in this study to be associated with having a VLBW infant in the border counties (Table 11 and 12). As discussed earlier, despite overall low rates of smoking in the border region this was a statistically significant factor among the women having a VLBW birth in the border counties. Also, as discussed in Chapter 1, prematurity and LBW births are strong predictors of infant mortality, and it is documented that having a previous preterm birth increases the risk of having a subsequent LBW/premature infant (Mathews et al., 2015). This was a similar finding by Chao et al., who found an association of having a previous LBW/preterm baby with infant mortality in Antelope Valley in California (2010). Interestingly, although inadequate prenatal care is associated with VLBW, it was not a significant contributor in the border region for preventing VLBW births.

4.7 Programs Addressing Feto-Infant Deaths in U.S. Mexico Border States

There are currently various programs that focus on preventing infant mortality and improving pregnancy outcomes and the health of women, infants, and children. Unfortunately, many programs may not be available in all areas of the border region or border states, and undocumented immigrant women may have difficulties or be ineligible assessing many of these programs.

4.7.1 Title V Block Grant

All U.S. states receive federal funding from the Maternal and Child Health Bureau (MCHB) in the Health Resources and Services Administration (HRSA) through the Title V Block Grant. This is a formula grant awarded upon submission of an application that includes a plan that addresses health services needs for women, children (1-21 years of age), and infants within the state. In addition, each state is required by law to submit an annual application and
conduct a state needs assessment every five years to receive the funds (Health Resources and Services Administration, ) The formula grant was designed to create federal and state partnerships that enable each state to address the healthcare and health disparities of the target populations within their states (Maternal and Child Health Bureau, 2016b). Strengths of the grant are that it is data-driven and flexible within each state, and uses a three-tiered national performance measurement framework that includes: National Outcome Measures (NOMs), National Performance Measures (NPMs), and State Performance Measure (SPM) / State Outcome Measure (SOM) (which both are state-initiated measures). All states report on NOMs if the data is available. Also, each state is required to choose a minimum of five NPMs, but can use as many NPMs and state-initiated measures as needed, based on the priorities identified in their needs assessment. State and national data are used to track the prevalence of the NOMs and NPMs, in addition to indicators developed addressing SPMs and SOMs. In 2018 none of the border states had developed SOMs (Maternal and Child Health Bureau, 2016a).

Table 14 shows the annually submitted NOMs for which all states collect prevalence data. Although all border states track prevalence on NOMs that focus on birth outcomes such as LBW, VLBW, prematurity, and infant mortality, at the moment, no cross-collaboration exists in providing interventions to improving those health issues jointly or developing joint strategies to be applied to the border counties across the four border states.

Table 15 shows the NPMs chosen by all U.S. states. However, only three of the NPMs (1, 4, and 12) were chosen by all four border states. Border states are missing a tremendous opportunity afforded by the grant to collaborate in addressing maternal and infant health issues affecting the border counties within the four border states by choosing national measures and developing state-initiated measures that can be applied and tracked across border states and border counties. If all four states addressed NPMs for low-risk Cesarean delivery, risk-appropriate perinatal care, adolescent well-visits, smoking, and adequate insurance, in addition to well-women visits and breastfeeding it would be a resourceful way to address risk factors that can affect LBW, VLBW, and infant mortality.
Table 16 shows the SPM that states are measuring in 2018. Similar to the national measures, none of the SPM developed to address the same health issue across all four border states. This is another area where all four states could agree to track the same SPM and develop similar strategies to address infant mortality across the border counties. For instance, all four states could choose to have an SPM to quantify Infant Mortality Disparities in the border counties. Then each state could apply similar interventions, such as making prenatal care more assessable, targeting pregnant women with diabetes or previous preterm births in border counties to have appropriate medical follow-up.

Table 14: Title V Block Grant National Outcome Measures as of 2018.

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<th>National Outcome Measure&lt;sup&gt;a&lt;/sup&gt;</th>
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<td>Severe Maternal Morbidity</td>
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<td>Maternal Mortality</td>
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<td>NOM 8</td>
<td>Early Elective Delivery</td>
<td>NOM 19</td>
<td>Overall Health Status</td>
</tr>
<tr>
<td>NOM 9</td>
<td>Perinatal Mortality</td>
<td>NOM 20</td>
<td>Overweight/Obesity</td>
</tr>
<tr>
<td>NOM 9.1</td>
<td>Infant Mortality</td>
<td>NOM 21</td>
<td>Uninsured</td>
</tr>
<tr>
<td>NOM 9.2</td>
<td>Neonatal Mortality</td>
<td>NOM 22.1</td>
<td>Child Vaccination</td>
</tr>
<tr>
<td>NOM 9.3</td>
<td>Postneonatal Mortality</td>
<td>NOM 22.2</td>
<td>Flu Vaccination</td>
</tr>
<tr>
<td>NOM 9.4</td>
<td>Preterm-Related Mortality</td>
<td>NOM 22.3</td>
<td>HPV Vaccination</td>
</tr>
<tr>
<td>NOM 9.5</td>
<td>SUID Mortality</td>
<td>NOM 22.4</td>
<td>Tdap Vaccination</td>
</tr>
<tr>
<td>NOM 10</td>
<td>Drinking During Pregnancy</td>
<td>NOM 22.5</td>
<td>Meningitis Vaccination</td>
</tr>
<tr>
<td>NOM 11</td>
<td>Neonatal Abstinence Syndrome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOM 12</td>
<td>Newborn Screening Timely Follow-Up</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


<sup>a</sup> Tracked by all states if data is available.
Table 15. Title V Block Grant National Performance Measures by border states as of 2018.

<table>
<thead>
<tr>
<th>National Performance Measures</th>
<th>Measure Short Name</th>
<th>Number of States</th>
<th>Arizona</th>
<th>California</th>
<th>New Mexico</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPM 1</td>
<td>Well-Woman Visit</td>
<td>50</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>NPM 2</td>
<td>Low-Risk Cesarean Delivery</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPM 3</td>
<td>Risk-Appropriate Perinatal Care</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPM 4</td>
<td>Breastfeeding</td>
<td>49</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>NPM 5</td>
<td>Safe Sleep</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>NPM 6</td>
<td>Developmental Screening</td>
<td>42</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>NPM 7</td>
<td>Injury Hospitalization</td>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>NPM 8</td>
<td>Physical Activity</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPM 9</td>
<td>Bullying</td>
<td>15</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPM 10</td>
<td>Adolescent Well-Visit</td>
<td>39</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>NPM 11</td>
<td>Medical Home</td>
<td>47</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>NPM 12</td>
<td>Transition</td>
<td>37</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>NPM 13</td>
<td>Preventive Dental Visit</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>NPM 14</td>
<td>Smoking</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>NPM 15</td>
<td>Adequate Insurance</td>
<td>15</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arizona</th>
<th>California</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPM 1: Percent of third-graders with dental sealants on their permanent molar teeth</td>
<td>SPM 1: Percent of women with the appropriate weight gain during pregnancy</td>
</tr>
<tr>
<td>SPM 2: Number of home visitors trained to promote physical activity among women.</td>
<td>SPM 2: Percent pregnancies that are mistimed or unwanted among women with a recent live birth</td>
</tr>
<tr>
<td>SPM 3: Number of providers supported to better educate families about the importance of immunization.</td>
<td>SPM 3: Percent of births among adolescents, ages 15-17 years.</td>
</tr>
<tr>
<td>SPM 4: Increase the number of school-based sealant programs in rural communities across Arizona.</td>
<td>Percent of Children with Special Health Care Needs (CSHCN) with select conditions who have special care center (SCC) team report documenting visit to subspecialist within 90 days of California Children’s Service (CCS)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>New Mexico</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPM 1: Percent of very low birth weight (VLBW) infants born in a hospital with a Level III+ Neonatal Intensive Care Unit (NICU)</td>
<td>Percent of CYSHCN and their families who received the supports and services necessary to be integrated into their communities</td>
</tr>
<tr>
<td>SPM 2: Percent of infants placed to sleep on their backs</td>
<td>SPM 2: Percent of Texas WIC participants, ages 2-5, in the overweight/obese range</td>
</tr>
<tr>
<td>SPM 3: Rate of Victims of Child Abuse per 1,000 Children in the Population</td>
<td>SPM 3: Infant Mortality Disparities: Ratio of Black to White infant mortality rate</td>
</tr>
<tr>
<td>SPM 4: Teen Birth Rate, Girls ages 15 to 19 years</td>
<td>SPM 4: Percent of young adults (ages 18-24) who visited a doctor for a routine checkup in the past year</td>
</tr>
</tbody>
</table>


### 4.7.2 Healthy Start

HRSA provides funding for other programs to address maternal and child health gaps that may still exist in a community despite Title V funding. One of these programs is Healthy Start, which a grant awarded to community-based organizations, health centers, universities, and health departments that apply to receive these funds (Maternal and Child Health Bureau, 2018a). Currently, 100 organizations are funded in 37 states, which include 74 urban, 21 rural, three tribal and four border area (Healthy Start EPIC Center, n.d. b). Unfortunately, this programs may
not reach all border county residents or may be hard to access. While throughout the border states there are numerous organizations funded, the only funded currently border organizations are in the counties of Laredo, TX; El Paso, TX; Santa Cruz, NM; and San Diego, CA (Healthy Start EPIC Center, n.d. a). Therefore, residents at further distances from these locations in the border counties may not have access to Healthy Start services.

Healthy Start mostly serves communities that have an infant mortality rates of at least 1.5 times higher than the national average, and aims to reach women of reproductive age, pregnant women, women that have recently given birth, infants, and families from birth to a child’s second birthday (Healthy Start EPIC Center, n.d. b). This program uses the Life Corse approach and assesses participant’s needs to aid with access to medical, social, behavioral, educational, and supportive services. It also aims to engage community partners to improve services. Some of the services that participants can seek are well-woman and well-baby care visits, prenatal care, family planning, depression screening, parenting support, health education, and connection to services (Maternal and Child Health Bureau, 2018a). Enrollment may vary by states, but this is a program that directly addresses factors contributing to infant mortality.

4.7.3 Maternal, Infant, and Early Childhood Home Visiting Program (MIECHV)

Another program is the Maternal, Infant, and Early Childhood Home Visiting Program (MIECHV) funded through MCHB, and in partnership with the Administration for Children and Families (ACF). The funding is provided to states, territories, and tribal entities through formula grants, innovation grants, and for tribal programs to develop and implement voluntary, evidence-based programs that meet the needs of their communities. As of 2017, all the four border state health departments receive formula funding and Arizona, California and New Mexico received tribal program funding. The amount of funding varies by state, and each is required to spend most of the funding to implement promising home visiting models that are evidence-based and work with the infrastructure of the state. In addition, grantees must show improvement in four of six benchmarks domains set by legislation. The domains are 1) maternal and newborn health, 2)
reduction in child injuries, abuse, and neglect, 3) school readiness and achievement, 4) reduction in crime or domestic violence, 5) family economic self-sufficiency, and 6) coordination and referral for other community resources and supports (Maternal and Child Health Bureau, 2018c).

MIECHV’s goals are to improve maternal and child health by providing voluntary, planned home visiting services conducted by health, social service, and child development professionals to families enrolled. The visits include many services such as supporting preventive health and prenatal practices; educating mothers on breastfeeding and care for their infants; use positive parenting techniques; and working with mothers to set goals for the future, continue their education, and find employment and child care resolutions (Maternal and Child Health Bureau, 2018c). Although, this programs can address risk factors for infant mortality and adverse pregnancy outcomes it may not be available to families in all border counties.

4.7.4 Collaborative Improvement and Innovation Networks (COIINs)

Another program available to address maternal and child health is the Collaborative Improvement and Innovation Networks (COIINs) which are interdisciplinary teams of leaders at the federal, state, and local level. These teams collaborate to address a problem in their community, and CoIIN provides a way for participants to self-organize, forge partnerships, and take coordinated steps to address complex issues through quality improvement, collaborative learning, and original activities.

Various COIIN groups are addressing many different health topics that align with Title V Block grant priorities and are supported and funded by HRSA. For instance, the Infant Mortality CoIIN and its participating teams composed of states strive to reduce infant mortality in areas with high annual rates of deaths, disparities, and related perinatal outcomes (Maternal and Child Health Bureau, 2018b).

One of the teams is the Border States Project Concern International (PCI) composed of members that include a Border Healthy Start Leads, a State Title V delegate, and a panel of experts and technical advisors from all four border states. This team is using three-year funding it
received for 2018-2020 to create a network of HRSA-funded Healthy Start programs expanding the border region counties in the four border states and structured around common standards and strategies. The team’s focus is to develop improvement strategies that address the social determinants of health with the purpose of increasing first-trimester prenatal care by 10% among women in the border counties (Border States CoIIN, 2018). This program is promising in the border region because it has the potential to fill some of the gaps in maternal and child health services that may exist. Furthermore, increasing the access to prenatal care can aid by addressing the risk factors found in this study that may increase the odds of having preterm and LBW infants, which contributes to the infant mortality.

4.7.5 Other Maternal and Child Health Programs

In addition to these programs, states have Child Mortality Review Committees or Infant Mortality Committees that are tasked with reviewing all or a sample of all deaths in their state and determine preventative strategies to recommend. Also, there is a multitude of national, community-based organizations, and non-profit organizations that focus at the local level to improve maternal and infant health and address gaps that may exist in services for pregnant women. Some of these programs include March of Dimes, Association of Maternal and Child Health Programs, and W.K Kellogg Foundation. Unfortunately, the focus may not be border-wide and resources are often limited.

In summary, although there are programs that address infant mortality, the programs are limited in resources, and not all are available border-wide. Therefore women in some regions on the border may have access to more service than in other areas of the border. Also, since many of these programs are federally funded, undocumented immigrants do not have access to them, which can be another reason why a woman residing in the U.S. may seek prenatal care in Mexico. Through a collaboration of border states, a lot of these efforts could be coordinating between states and concentrated in the border region that sees high rates of infant mortality and
excess deaths, which would improve pregnancy outcomes in the U.S. Mexico border region as a whole.

4.6 LIMITATIONS AND STRENGTHS

It is important to consider the limitations of this study. Generalizability is limited because the reference group did not include education, which usually is included in the PPOR analysis. Results of this study may not be comparable to other PPOR analyses. The variables available to study were limited by what is asked in the birth and death certificates, and not all variables were available in all states because of different versions of the birth certificate in use at the time the data were collected. Also, missing data in some of the variables of interest were limited to only those with the data. Therefore, residual confounding could have affected the results. Also, there is the potential of recall bias in all variables in the death and birth certificate that are self-reported. Another limitation is that the number of infants that may have been born in the border, but died in Mexico (resulting in their death not being recorded in the U.S.) is not known. Considering the sizeable migratory movement across the border in borders counties, the number of uncounted deaths could be more than minimal.

The strengths of the study are also important to consider. The large dataset allowed the researcher to fully utilize the PPOR approach to identify excess deaths and causes of infant mortality. Also, very few infant-deaths were unlinked in the dataset enabling a near total population to be included in the study.
Conclusions

Feto-infant mortality is a complex and multifactorial health problem. Social and behavioral factors play a role in pregnancy outcomes. The findings of this study suggested that the border counties and states should focus prevention efforts in targeting risk factors associated with the Maternal Health and Prematurity (MHP) and should focus on reducing very low birthweight infants. Intervention programs should target preconception health, maternal health behaviors before pregnancy, high-risk obstetric care, and perinatal care among women living in the border regions. Due to the limited financial resources available in the region, adopting the Life Course approach for all aspects of women’s health would be a worthwhile investment and affect the most individuals in the long run.

Furthermore, a vast majority of research supports the fetal origin hypothesis, which shows that the period of gestation has substantial effects on the developmental health outcomes for an individual ranging from infancy to adulthood (Almond & Currie, 2011). Therefore health interventions to prevent LBW and VLBW births need to start early in a woman’s life before she becomes pregnant. For instance, smoking prevention programs should focus on targeting women in early youth (as children and adolescents), before they become pregnant, and smoking cessation programs should directly target women of reproductive age (15-45 years of age), especially if they are pregnant in an effort to prevent VLBW births among women in the border region. Also, prematurity (also a primary cause of VLBW) is not only associated with smoking, but also with pre-pregnancy maternal morbidities, alcohol use during pregnancy, teen pregnancy, and birth defects. Therefore other intervention programs in the border region should focus on preventing these factors early in a woman’s life, such as focusing on folic acid use, maintaining a healthy weight, and reducing risks of hypertension throughout a woman’s life.

Although the descriptive data did not control for confounders, the data suggested that perhaps women less than 20 years of age should receive particular focus in the border region to prevent infant deaths, such as increased teen pregnancy prevention activities and more medical
follow-up once pregnant. It must be noted that in the PPOR analysis there is not a minimum age cut off, so the “less than 20 years” age group in this study included mother’s ages 10-14 years old. Although this number was small and there were no differences by regions studied, the data might not be fully comparable with teen birth rates which are typically calculated for slightly older girls. Much more research is needed to determine if, after controlling for cofounders and restricting age, the difference persists among women 15-19 years old experiencing a death in the border counties.

Perhaps most importantly, maternal risk factors and also diseases do not stop at the international borderline. The border states need to collaborate with each other, and with border counties and states in Mexico, to improve our capacity to address and reduce infant mortality along the U.S.-Mexico border.
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# Appendix

Table A. Five Implausible Combinations of Gestational Age and Birthweight for Births and Fetal Deaths.

<table>
<thead>
<tr>
<th>Combinations for Exclusion</th>
<th>Gestation</th>
<th>Birthweight</th>
<th>Plurality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 20</td>
<td>≥ 500</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>≥ 20 and &lt; 24</td>
<td>≥ 2,000 grams</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>≥ 24 and &lt; 28</td>
<td>≥ 3,000</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>≥ 28 and &lt; 32</td>
<td>4,000</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>≥ 32 and &lt; 47</td>
<td>&lt; 1,000</td>
<td>1</td>
</tr>
</tbody>
</table>

Vita

Dyanne Herrera was born in Dominican Republic and was raised in Orlando, Florida. She completed her Bachelors of Science degree in Microbiology from The University of Florida (UF) in 2002. From 2002-2006, she worked as a Research Coordinator at The University of Florida for a NIH funded study looking at Ethnic differences in pain perception. In 2006, she began pursuing her Master in Public Health with a concentration in Epidemiology at UF and graduated in 2009. After graduation, she was accepted as one of the fellows for Class VII cohort of the CDC/CSTE Applied Epidemiology Fellowship. This was a two year fellowship program to gain public health experience at a health department in the U.S. During the fellowship, from 2009-201, Ms. Herrera was mentored Dr. Jill McDonald and worked in El Paso, Texas to increasing maternal and child health capacity in the U.S.-Mexico Border Region. She authored her first article entitled “Cervical cancer screening in the U.S.-Mexico Border Region: A bi-national analysis” (2012) and received the Hillary B. Foulkes Memorial Award in recognition of her outstanding achievement and commitment to excel as a CSTE/CDC Epidemiology Fellow.

After the fellowship, Ms. Herrera worked as a Maternal and Child Health Epidemiologist and Office Chief of Assessment and Evaluation at Arizona Department of Health Services from 2011-2014. In 2014 she began perusing her third degree in Interdisciplinary Health Sciences, while at the same time working at Texas Tech Health Science Center as a Lead Analyst and later as Assistant Director of Institutional Research. Ms. Herrera. In 2018, she completed her research examining feto-infant mortality in the U.S. – Mexico Border Region with Dr. Christina Sobin as her faculty advisor, and graduated with her Ph.D. from the University of Texas at El Paso.

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This thesis/dissertation was typed by Dyanne Herrera.