# HAZARD ANALYSIS OF MORTALITY AMONG TWINS AND TRIPLETS IN THE UNITED STATES: FROM 20 WEEKS GESTATION THROUGH THE FIRST YEAR OF LIFE

A Dissertation

by

BETHANY SUZANNE DESALVO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2010

Major Subject: Sociology

# HAZARD ANALYSIS OF MORTALITY AMONG TWINS AND TRIPLETS IN THE UNITED STATES: FROM 20 WEEKS GESTATION THROUGH THE FIRST YEAR OF LIFE

A Dissertation

by

BETHANY SUZANNE DESALVO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Approved by:

| | |
|---|---|
| Chair of Committee, | Dudley L. Poston, Jr. |
| Committee Members, | Mark Fossett |
| | W. Alexander McIntosh |
| | Rogelio Saenz |
| Head of Department, | Mark Fossett |

May 2010

Major Subject: Sociology

# ABSTRACT


Hazard Analysis of Mortality Among Twins and Triplets in the United States: From 20 Weeks Gestation Through the First Year of Life. (May 2010)

Bethany Suzanne DeSalvo, B.A., University of Pittsburgh;

M.A., Indiana University of Pennsylvania

Chair of Advisory Committee: Dr. Dudley L. Poston

Infant mortality is viewed as an important indicator of the health and social conditions of a population. However, the infant mortality rate in the United States is estimated to be much lower than those of other developed nations. This dissertation analyzes the hazard of fetal and infant death for twins and triplets in the United States between the years of 1995 and 2000. This dissertation had two main objectives: first, to examine the effects of the birthweight and gestational age on the hazards of fetal, neonatal, postneonatal, and infant death; and second, to better understand the timing of mortality among multiples during their early life. I show that after controlling for relevant characteristics of the mother and child, gestational age and birthweight significantly influence the hazard of mortality for twins and triplets.

The major finding in this dissertation shows that there is a higher hazard for twins than triplets. The unexpected higher hazard of mortality for twins compared to triplets may well be due to the social and demographic characteristics of parents of twins and triplets, particularly the possible use of Assisted Reproductive Technologies.

# DEDICATION

To Addison, your promise of life inspired this work,

To my parents Linda and Frank, for all of your support,

To my partner in life Dario, for your tolerance and love,

And to my sister Erica, for the love and laughter you have given me all of my life.

**ACKNOWLEDGEMENTS**

First and foremost, I thank my committee chair and life's mentor, Dr. Dudley L. Poston, Jr., who introduced me to demography and who believed in me when I did not believe in myself. I am also grateful to my professors and committee members who supported my work throughout graduate school.

I would like to thank my friends within the Sociology Department who have been extremely supportive including Yu-Ting Chang, Danielle Deng, Calixto Melero, Bruce Robertson, and Carlos Siordia. Especially, I would like to thank Eugenia Conde-Dudding who was my companion on our trip around the world. I am grateful to Chris Cherry who is a constant source of laughter and fun. I would also like to thank Adrian James who motivates and supports me constantly. Tessa Maring-Goolsby has been a true friend since our first course together in the Fall of 2006. Finally, the "Census Aggies," Drs. Rachel Cortes, Christine Guarneri, and Lindsay Howden who have made my work at the Census a fun adventure.

I would like to thank my family, including my stepparents William Wallace and Jan DeSalvo who have supported my family for more than a decade, and my Aunt Martha who has always been on my side.

# TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

TABLE Page

TABLE Page

TABLE Page

TABLE Page

TABLE Page

TABLE Page

# CHAPTER I

# INTRODUCTION

Infant mortality may be viewed as an important indicator of the health and social conditions of a population. Sociologists have long considered infant mortality to be a sensitive indicator of the impact of socioeconomic disparities on the health of a population because of the vulnerability of newborns to substandard living conditions (Marx 1967). Although the United States is one of the wealthiest countries in the world, the infant mortality rate (IMR) still ranked 42nd among countries with available data in 2008, at an estimated 6.30 (CIA World Factbook 2008). Countries with infant mortality rates estimated lower than the United States in 2008 included Singapore (2.30), Sweden (2.75), Japan (2.80), Hong Kong (2.93), Macau (3.23), Iceland (3.25), France (3.36), Finland (3.50), Anguilla (3.54), Norway (3.61), Andorra (3.68), Malta (3.79), the Czech Republic (3.83), Germany (4.03), Switzerland (4.23), Spain (4.26), Israel (4.28), South Korea (4.29), Slovenia (4.30), Denmark (4.40), Austria (4.48), Belgium (4.50), Liechtenstein (4.52), Guernsey (4.53), Luxembourg (4.62), the Netherlands (4.81), Australia (4.82), Portugal (4.85), Gibraltar (4.91), the United Kingdom (4.93), New Zealand (4.99), Jersey (5.01), Canada (5.08), Ireland (5.14), Monaco (5.18), Greece (5.25), San Marino (5.44), Taiwan (5.45), Italy (5.61), the Isle of Man (5.62), and Cuba (5.93) (see Table 1.1) (CIA World Factbook 2008).

In this dissertation, I will analyze the hazard of death for fetuses that reached 20 weeks gestational age and infants who are part of a twin or triplet set born between

---

This dissertation follows the style of *Demography*.

1995-2000. This dissertation will allow for a deeper understanding regarding the timing of mortality among this highly sensitive group. Also, I will be able to understand which social and medical variables contribute to the death rates of twins and triplets in the United States as well as if these variables are the same for singletons. With an increase in multiple births in the United States, will the overall mortality rates for the United States increase? If so, by how much and to which subgroups?

To help place my dissertation research in broader perspective, I first ask why infant mortality is so high in the United States when we have expensive modern technology at our fingertips. In 2005, a total of 28,440 deaths occurred to children under the age of 1, which is 504 more deaths than in 2004 (MacDorman and Mathews 2008). In Chapter II I will explain some of the reasons for our increased rates in the United States compared to other countries, which includes how we operationalize mortality and race and ethnic concerns. This dissertation will also show that the increase in multiple births will yield more deaths as they already account for 15 percent of all infant deaths. Since the beginning of nationwide (by state) death registration in 1933, with the exception of 1957-8, the trend of infant mortality has either been steadily or rapidly declining. During the 1930's and 1940's, the IMR declined 4 percent per year; from 1950-1964, the rate of decline slowed to 1 percent per year; and from 1965 until the 1980, the IMR declined rapidly by an average of 5 percent per year (MacDorman and Rosenberg, 1993). From 1981 to 1989, the IMR declined to an average of 2 percent per year (Arias 2003). From 1990-2001, the IMR decreased 26 percent from 9.2 to 6.8 but has remained stable since. Between 1990 and 2004, the neonatal mortality rate declined from 5.8 to 4.5; the post neonatal mortality rate declined from 3.4 to 2.3; and the fetal mortality rate declined from 7.49 to 6.20 (MacDorman & Matthews 2008). The decrease in the death rates has slowed since the mid 1990's, which may be due to the increase in the number of low birthweight and preterm births which is correlated with the increase in the number of multiple births (see Table 1.2, 1.3, 1.4).

Preterm and low birthweight births have increased steadily in the past few years which may be due to the increase in multiple births and to advancements in medical techniques such as cesarean sections and induction of labor (Fretts 2005; Canterino et al, 2004; Ventura et al, 2000; Greb et al 1987). The percentage of low birthweight and preterm births has been increasing since the mid-1980's. Infants weighing less than 1,000 grams accounted for only 0.8 percent of births but 48.2 percent of infant deaths in the United States in 2005 (MacDorman and Mathews 2008). Only 0.8 percent of births occurred at less than 28 weeks of gestation but these 0.8 percent accounted for 46.4 percent of all infant deaths in 2005. More than half of infants born preterm and/or low birthweight are born in a multiple delivery, and one-fourth of all low birthweight infants are born in a multiple delivery (Martin et al. 2003).

The *Objectives of Healthy People of 2010*, a set of national initiatives being pursued in the United States by several federal agencies such as the National Institutes of Health, the Food and Drug Administration, and the Centers for Disease Control and Prevention, has as one of its goals the reduction of the IMR in 2010 to 4.5 infant deaths per 1,000 live births. Unfortunately, previous sociological studies have not paid special attention to the rise of twins and triplets in our population. The reasons for the inflation of multiples will be discussed later in this dissertation. This rise in the prevalence of multiple births and, thus, mortality among multiples has been virtually ignored by demographers. Women who are most likely to have multiples are those who are older and/or have utilized Assisted Reproductive Technology (ART). Traditional studies of infant mortality would theorize that women who are older or have enough money to utilize expensive ART treatments, would be more likely to have access to healthcare, and thus have infants who are healthier. However, because of the high risk of mortality among multiples, these mothers' infants are more likely to suffer mortality. Thus, this subgroup will suffer a higher infant mortality rate, which is opposite to the idea that a high infant mortality rate is an indicator of poor population health. In fact, a high infant mortality rate among multiples is actually an indicator of social affluence.

In order to understand this contradiction regarding infant mortality as an indicator of population health, in my dissertation I will analyze the hazard of fetal, neonatal, postneonatal, and infant mortality for twins and triplets in the United States from 1995-2000. This will allow for a broader understanding of the hazard of mortality among fetal and infant twins and triplets, so that appropriate comparisons can be made in order to address the question as to the utility of mortality as an indicator of a populations health and social conditions.

When a pregnant woman is carrying more than one fetus at a time, she is said to have a multiple pregnancy. Multiples can be carried in sets of two or more. Two fetuses are called twins, three fetuses are called triplets, four are called quadruplets, and so on. Twins can be either identical (monozygotic) or fraternal (dizygotic). More than 3 percent of babies in the United States are born in sets of two, three, or more; and 94 percent of these multiple sets are twins (Martin et al. 2003).

Identical or monozygotic twins occur when one fertilized egg splits and develops into two fetuses; this is a result of the fertilization of a one ovum by one spermatozoon. The split of the fertilized egg is considered an "accident" and usually occurs during the first 14 days after conception. The two fetuses usually share one placenta and have the same chromosomes. Identical twin deliveries occur worldwide at a rate of 3.5 to 4.0 per 1,000, regardless of the mother's age or birth order; there is virtually no variation in this occurrence (Pison 2000). Also the rate of identical twinning is the same for all mammals, except for armadillos which consistently have quadruplet and octuplet identical twins (Pison 2000). Also, all women run an equal risk of having identical twins (Bulmer 1970). Because there is a high incidence of malformation among monozygotic twins, the probability of antenatal mortality is much higher than the probability of mortality for dizygotic twins or singletons. According to Bomsel-Helmreich and Mufti (1995), major malformations are found in 2.3 percent of monozygotic twins compared to one percent of singletons, and minor malformations are found in 4.1 percent of monozygotic twins and only 2.5 percent of singletons.

Fraternal or dizygotic twins develop when two separate eggs are fertilized by two different spermatozoa. In this case, each twin usually has its own placenta and has about 50 percent similar chromosomes. Fraternal twins can be of both sexes and are much more common than identical twins. Because each ova is fertilized by a spermatozoon, the fraternal twins are no more similar, from a genetic standpoint, than siblings born separately. The proportion of fraternal twins in the population varies considerably. The main factors influencing the variation are the age of the mother, the order of the birth, individual and family characteristics, and medical treatments (these topics will be discussed in more detail in the literature review – Chapter II). Between 1980 and 2003 in the United States, the number of twin births increased by 66 percent (Strobino et al. 2007).

Triplets and other higher-order multiples can result from three or more eggs being fertilized, one egg splitting twice (or more), or a combination of both. A set of higher-order multiples may contain all fraternal siblings or a combination of identical and fraternal siblings.

The triplet plus birth rate (TPBR) is the number of live births in triplet and other higher-order deliveries per 100,000 live births. Change in the TPBR has been especially dramatic; in the United States, it has increased five-fold from 37.0 in 1980 to 176.9 in 2004.

During the past thirty years, there has been a dramatic increase in the multiple birth rate (MBR) in the United States. The MBR is the number of live births in all multiple deliveries per 1,000 live births. On average, the multiple birth rate has been increasing 2 percent per year since 1980 (Strobino et al. 2007). With an increase in the MBR comes an increase in the risk of mortality of the fetus and/or infant.

There are several types of mortality that should be discussed when trying to understand the impact of multiples on mortality rates. Most fetuses never reach terms because they fail before clinical recognition. Boklage (2005) notes that "projections indicate term survival of no more than one in four natural conceptions, and no more than one in 50 natural twin pairs." Booklage (2005) also notes that more than one in eight pregnancies start with twin fetuses. Because of the extremely high mortality rate among early neonates, in my dissertation research I will exclude all fetuses that suffer mortality before 20 weeks gestation. Instead, I will concentrate on later fetal, neonatal, post-neonatal, and infant mortality among twins and triplets.

Fetal mortality refers to the death of a fetus over 20 weeks or higher gestational age. The fetal mortality rate (FMR) refers to the number of fetuses who died after 20 weeks or higher gestation, per 1,000 vive births. In 2003, the FMR in the United States was 16.52 for twins and 22.31 for triplet-plus gestations (MacDorman et al. 2007). Neonatal death refers to the death of an infant after birth but before the infant is 28 days old. The neonatal mortality rate (NMR) is the number of deaths for neonates per 1,000 live births.

Post-neonatal mortality refers to the death of an infant after 28 days of age and before 365 days of age. The postneonatal mortality rate (PNMR) rate calculated as the number of post-neonatal deaths per 1,000 live births.

Finally, infant mortality refers to deaths of infants before one year of age. By definition, the infant must be born in order to be able to die. Fetal deaths are not counted as infant deaths. The infant mortality rate is the most cited index of mortality in the literature dealing with multiple births. The IMR is the number of deaths to infants before the age of one per 1,000 live births.

The increase in the mortality of twin and triplet fetuses and infants occurs because they, more likely than singletons, are at the risk of suffering from the negative health effects of premature birth, low birthweight, twin-transfusion syndrome, preeclampsia and gestational diabetes.  Triplet-plus multiples are at even higher risk of these adverse outcomes that potentially may lead to disabilities later in life including ventricular hemorrhages and cerebral palsy (Polin and Frangipane 1986).  Each additional fetus increases the risk of mortality (Salihu 2003).

In 2005, multiples accounted for 3 percent of live births and 15 percent of infant deaths in the United States.  Specifically, 90 percent of triplets are born preterm making triplet-plus births 12 times more likely to die within the first year than singletons (Salihu 2003).  For multiple births, the infant mortality rate was 31.50, more than 5 times the rate of 6.0 for singletons in 2005.  The IMR for twins was 29.84 and 59.60 for triplets (MacDorman and Matthews 2008).  Martin and Taffel argue that the main reason for the increased IMR for multiples is due to the fact that at least half of all twins and 90 percent of higher order births are of low birth weight (LBW) and born preterm (1995). The risk of fraternal multiple births is increased when fertility-enhancing therapies are utilized. Forty-nine percent of infants born through ART in 2005 were born in multiple-birth deliveries, compared with 3 percent in the general U.S. population (Wright et al, 2008). The CDC attributes more than 40 percent of the triplet and higher order births in 1997 to ART and another 40 percent to ovulation-inducing drugs (2000).

Understanding why fetuses and infants die provides us with a better representation of the health of our nation.  Since twins and triplets are the most vulnerable, their mortality prospects should be the most sensitive to health issues. Although work has been done in the area of obstetrics and gynecology on this topic, the demographic literature is sparse. This is a shame because rich datasets are available, an example of which has been given above.

The main contribution of my dissertation research is the teasing-out of the variables which affect mortality rates differently among twins and triplets; variables that affect the mortality probabilities for singletons affect twins and triplets differently. I will estimate hazard models of the various forms of fetal and infant mortality. Such analyses have not been previously conducted with nationally representative samples in the United States.

The analyses conducted in this dissertation will help to achieve my main goal of drawing research attention to the hazard of death among multiples. There will be eight chapters in this dissertation. Following this introductory chapter, Chapter II reviews the literature related to mortality among multiples and evaluates the strengths and weaknesses of previous studies. Chapter III describes the Matched Multiple Birth Dataset and its history, explains the methodology that will be utilized in this dissertation, and presents the hypotheses. Chapters IV, V, VI, and VII show the results of the Cox Hazard models for twin and triplet fetal, neonatal, postneonatal, and infant mortality subsequently. Each of these chapters will include individual models for twins-only, for triplets-only, and a triplet-dummy. Chapter VIII is the final chapter, which concludes the findings and presents ideas for future research.

# CHAPTER II

# LITERATURE REVIEW

This second chapter of my dissertation reviews the literature related to the prevalence of multiple births and mortality among twins and triplets from 20 weeks gestation through the first year of life. My review will cover several topics. First I will discuss current trends of twin and triplet births in the United States. Then I will move to the definition and measurement of fetal and infant death as well as give short descriptions of the definitions and measurements utilized in other countries. I will then discuss the importance to demographers of studying fetal and infant mortality. Next, I will provide the rates of death and emphasize the need for understanding race and ethnic disparities. Then, I will move to explaining the history of infant mortality in the United States and follow with a section on the major causes of death for twins and triplets in the United States. Finally, I will conclude with a discussion of why this dissertation topic is important in today's social context. Hopefully, my literature review will give the reader the opportunity to understand the past, present, and future of the dynamics of infant mortality in the United States as well as the part that multiple births may play in the future of the fetal and infant mortality structure in the United States.

## Trends of Twin and Triplet Births in the United States

The twin birth rate increased from 18.9 in 1980 to 32.2 per 1,000 live births in 2005; this is a record high level and a 70 percent increase. The triplet-plus birth rate (TPBR) soared by greater than 400 percent between 1980 and 1998, but has since decreased slightly. The TPBR declined by 6 percent from 2004 to 2005 at 176.9 per

100,000 births (NCHS 2007). Despite small fluctuations in the TPBR, levels remain 4-fold higher than those before the introduction of fertility therapies in the early 1980s. The reduction of the TPBR could well have been due in part to the stipulation of the American Society of Reproductive Medicine limiting the number of embryos that could be transferred to women during Assisted Reproductive Technology (ART) procedures (NCHS 2007).

About one-third of the change in the rate of multiple gestations is due to increases in women over 30 years old having children (Reddy et al. 2005). Strobino and colleagues (2007) argued that the birth rates for women 30 years of age and above rose in 2005 to levels not seen in almost 40 years, which paralleled the rise in the preterm and low birthweight rates. Preterm births rose to 12.7 percent in 2005 and low birthweight infants rose to 8.08 percent (MacDorman and Mathews 2008).

The age-specific fertility rate for women aged 30-34 years in 2005 was 95.8 births per 1,000 women (NCHS 2007). The birth rate for this age group has risen 83 percent since 1975 and 19 percent since 1990 even though there was a 10 percent decline in the number of women in this age group (NCHS 2007). The birth rate for women aged 35-39 years was 46.3 births per 1,000 women, which is a 46 percent rise since 1990 (NCHS 2007). The birth rate for women aged 40-44 years rose from 8.9 to 9.1 births per 1,000 women between 2004 and 2005 (NCHS 2007). This age groups rate has doubled since 1981. The birth rate for women aged 45-49 increased to 0.6 births per 1,000 women in 2005 from 0.5 in 2004, which is the first increase since 2000 (NCHS

2007). The birth rate for women 50 years and over increased in 2005 to 417 from 374 in 2004 (NCHS 2007).

Another reason why the number of multiples has been increasing is the utilization of fertility therapy technologies. Fertility therapy technologies are thought to be a large contributor to the increase in multiple births, along with the shift in the maternal age distribution at childbearing (Blondel et al. 2002; CDC 2000 and 2002; Keith et al. 2002; Martin et al. 1998). About 45 percent of ART pregnancies result in twins and 7 percent in triplets-plus pregnancies (Wright et al. 2006). The NCHS (2007) reports that 17 percent of all twins and 40 percent of all triplets born in the United States in 2004 were due to ART therapies.

**Defining and Measuring Fetal and Infant Mortality**

Before defining specific types of death, I will first present the demographic definitions of "live birth" and "death" in general. A "live birth" is "the complete expulsion or extraction from its mother of a product of conception, irrespective of the duration of pregnancy, which after separation breathes or shows any other evidence of life"; and death is "the permanent disappearance of life any time after live birth has taken place" (Frisbie, 2006: 255-256). The definition of death "complements that of a live birth" (Estee, 372) which excludes all types of fetal deaths. The WHO "recommends that birth be considered live if the newborn shows any one of the following signs of life: heartbeat, breathing, umbilical cord pulsation, or voluntary muscle movement" (Haub and Yanagishita: 1991, 7). The United States follows this definition as well as the American College of Obstetricians and Gynecologists' recommendation to assist in "determining what should be considered a live birth: 'Heartbeats are to be distinguished from transient cardiac contractions; respirations are to be distinguished from fleeting respiratory efforts or grasps" (Siegel and Swanson, 2004: 371-371). These recommendations were put into place to ensure that the vital registration data derived from birth and death certificates are valid and reliable. This will ensure the highest possible accuracy in the data used in this dissertation.

Defining and measuring fetal and infant mortality is more difficult than it may seem. I will first define fetal mortality, and then infant mortality. Fetal death "refers to the disappearance of life prior to the expulsion or extraction from its mother of a product of conception" (Siegel and Swanson, 2004: 372). The United States follows the recommendation of the United Nations which breaks the period of gestation into four classes: under 20 completed weeks, 20-27 completed weeks, 28 to 36 completed weeks, and 37 completed weeks and over. Gestations 28 weeks and over are considered to be late fetal deaths and gestations less than 28 weeks are considered to be early fetal deaths. This dissertation, following the suggestions of the National Center for Health Statistics, will only calculate fetal deaths for those fetuses of 20 weeks gestation or more. Siegel and Swanson (2004: 295) warn that "the data on late fetal deaths are subject to substantial error introduced by incorrect reporting of gestational age." This occurs because the determination of age is complicated and relies on the skill of the medical attendant making the decision. There will likely be some error in the reporting of late fetal deaths in the data used in this dissertation. But I will assume, as do other fetal death researchers, that the reporting error is close to being randomly distributed.

In some countries, the definitions of fetal death vary, making international comparisons tricky. For example, some countries include live-born children dying in the first 24 hours after birth as fetal deaths. In the United States, we would consider this an "infant death." Also, in many countries, fetal deaths are not even reported.

Next I will define infant mortality. According to Frisbie (2006: 255), "infant mortality refers to death within the first year of life to persons born alive." Until the late 1800s, infant mortality rates of 200 plus per 1,000 births were common among developed countries. But, during the last part of the 19th century, almost all countries experienced sharp decreases in their IMRs. In the Western world, this was due to reductions in infectious and parasitic diseases. In 2005, the IMR for all births and deaths in the United States was just under 7 deaths per 1,000 live births contrasted with an IMR of over 100 in 1915-1916 (CIA World Factbook 2009).

The 2005 IMR for race/ethnic groups is at its highest for non-Hispanic blacks at 13.63, and at its lowest for Cubans at 4.42. The rate for Central and South Americans was 4.68, for Asian or Pacific Islanders, including persons of Hispanic and non-Hispanic origin, it was 4.89, for Mexicans, 5.53, for American Indians or Alaskan Natives, including persons of Hispanic and non-Hispanic origin, 8.06, for Puerto Ricans, 8.30, and for non-Hispanic whites, 8.76 (see Table 2.1). The non-Hispanic black IMR is obviously the highest of all of the groups. Black infant mortality declined between 1983 and 2004 from 19 to 14 infant deaths per 1,000 live births. However, the racial gap persists.

The United States has a relatively high IMR compared to other developed countries (see Chapter I for comparisons among countries). In an attempt to explain this disparity, I will discuss two possible reasons for its occurrence. First, the United States operationalizes an infant death as a product of a live birth that shows any sign of life (see earlier discussion in the beginning of this chapter), while other countries are not as inclusive. In fact, the United States counts many events as infant deaths that other countries would count as fetal deaths. For instance, Austria and Germany do not consider an infant death if it does not weigh at least 500 grams or 1 pound; in Switzerland, the fetus must be 30 centimeters or 12 includes long; in Belgium and France the fetus must have gestated for at least 26 weeks; and some countries do not even count an event as a death if the infant died before reaching 24 hours old. Healy notes that the United States is sure to have higher rates due to its measurement classifications (2006). However, an analysis of Haub and Yanagishita (1991) shows that statistical adjustments made in attempt to account for measurement differences still do not result in the United States' IMRs competing with the lowest levels of Japan and Sweden.

Another reason for the high IMRs in the United States can be traced to socioeconomic differences in our population. The mother's socioeconomic status has a great impact on the health of her fetus or infant. One of the leading causes of infant mortality in developed countries is congenital malformation, which is greatly affected by good nutrition and prenatal care. Poor and/or uninsured/underinsured mothers may lack the resources to be able to purchase these benefits, which endangers her offspring.

*Healthy People 2010* is a set of health objectives set by the United States government for the nation to achieve before 2010. One of the main objectives is to improve the health and well-being of women, infants, children, and families. This report noted that four causes of death accounted for more than 50 percent of infant deaths, namely, birth defects, disorders relating to short gestation and unspecified low birthweight, sudden infant death syndrome, and respiratory distress syndrome. In 2005, almost half of infant deaths had the same causes as noted in this report, but maternal complications replaced respiratory distress. Preterm birth and low birthweight deaths are among the leading causes of infant death and are disproportionately problems with twins and triplets.

The *Healthy People 2010* report also emphasizes the racial disparities among the deaths of infants. The Cuban population is the only subgroup that will meet the goal of reaching 4.45 deaths per 1,000 live births or less before the year 2010. The reasons for the racial and ethnic group disparity include risk factors such as preterm and low birth weight delivery, socioeconomic status, and access to medical care.

**The Importance of Infant Mortality**

In 1661, John Graunt was the first to quantify infant mortality in his analysis of the English Bills of Mortality. Graunt concluded that “one third of all that were ever quick, die under five years old” (1939: 9). The World Bank notes that the infant mortality rate is employed as a worldwide social indicator as a “critical test” for identifying countries as “superior health achievers” (Caldwell, 1986: 173). Pattnayak and Shai (1995) state that the IMR is an inverse proxy measure of development.

Gortmaker and Wise write that the IMR is “a synoptic indicator of the health and social conditions of a population” (1997: 147). In 1911, S.W. Newmayer stated that “the country which first recognizes its responsibilities to the child will receive the recognition of the world as being a civilized nation” (1911: 532).

The IMR was a popular index of health and social wellbeing in the 19th Century. William Farr, a health statistician in England’s General Registrar Office, said that the IMR was appropriate because infants were more sensitive than adults to common diseases and environmental conditions (Eyler, 1979). Farr’s student, Arthur Newsholme, added that the IMR represents specific age cohorts so it corrects the differences among communities in the average age of their populations (Eyler, 1979). Newsholme, the British Minister of Health and author of public health textbooks, influenced other public health officials to use the IMR as an indicator of the social environment of a society. He said that “infant mortality is the most sensitive index we possess of sanitary administration and of social welfare” (1889). If infants in general are still considered sensitive to outside effects, then multiples should be considered even more sensitive and a better index of social welfare. The research I undertake in my dissertation will allow me to address this claim.

During the 19th Century the use of the IMR was also seen a reliable indicator of the changing attitudes of communities and other groups toward children in the United States. Children were no longer seen as a purely economic resource, and death was not acceptable. Before this time, deaths were common and expected as a reflection of natural order. In a letter to the registrar, Farr wrote that “allowing infants to die is like an idolatrous tribe sacrificing its youth" (Eyler 1979: 479). This encouraged public health officials to use the IMR as the "best measure of the civilization of a race" (Anonymous; 1908 Knox, 1910: 8; Chenery, 1919). In 1921 during the Eleventh Annual Meeting of the American Child Hygiene Association, Herbert Hoover stated that "child welfare is a fundamental national principle and the nation… has the obligation of such measures toward its children… as will yield to them an equal opportunity at their start in life. This responsibility and duty is not based alone on human aspirations, but it also based on the necessity to secure physical, mental and moral health, economic and social progress by the nation. Every child delinquent in body, education, or character is a charge on the community as a whole and a menace to the community itself. The children of strong physique, of sound education and character, are the army with which we must march to progress."

**Rates of Death**

Late fetal deaths account for 49 percent of all deaths that occur between the 20th week of pregnancy through the entire gestational period. Fetal deaths mainly include deaths that were an involuntary loss in which the fetus showed no evidence of life upon delivery. MacDorman and Mathews reports that the total fetal mortality rate in 2005 was 6.22 which is not a significant increase from the 2004 rate of 6.20 (2008).

The reduction in the overall FMR could be due to changes in perinatal technologies such as fetal imaging, prevention of perinatal infections, effective treatment of maternal medical conditions, such as diabetes and chronic hypertension, and the aggressive management of labor and delivery (Cnattingius and Stephansson 2002).

Despite the improvements in FMRs for multiples in all races in 2005, the risk for fetal mortality for twins was 16.08; 27.18 for triplets-plus; and 5.85 for singletons. In 2005, non-Hispanic whites report the best outcomes with an FMR of 4.79 for all pluralities, 4.43 for singletons, 13.26 for twins, and 20.71 for triplets-plus. The next group with the lowest FMR was the Hispanic population with an overall FMR of 5.44, 5.17 for singletons, 16.12 for twins, and 39.14 for triplets-plus. The highest FMRs are those of the black population with 11.13 for all pluralities, 10.68 for singletons, 21.95 for twins, and 44.96 for triplets-plus (MacDorman and Mathews 2008).

Alexander and his associates (2005) argue that rates across plurality groups and fetal unadjusted mortality rates were consistently higher than average for unmarried teens; the rates were also positively associated with gravidity for age (calculated as having equal to or more than the following number of deliveries: 2+ for mothers <18 years, 3+ for mothers 18-21, 4+ for mothers 22-24 years, 5+ for mothers 25-29 years, 6+for mothers over 30 years), previous pregnancy loss, and tobacco use. Important to note about the study of Alexander and associates is that their data showed that women who had multiples were older and had lower-than-average risks of fetal death.

From 1995 to 1998, the neonatal mortality rate for singletons was approximately 4.5 neonatal deaths per 1,000 live births; for twins the rate was 23.65; for triplets the rate equaled 53.73; and the rate was 67.54 for quadruplets (Alexander et al. 2005). In 2005, the NMR was 10.73 for all pluralities. Alexander and colleagues (2005) found that neonatal mortality rates for all plurality groups were higher for women who were black or other/unknown race/ethnicities, unmarried, age less than 20 years, smokers, and mothers who had previous pregnancy losses. According to Shaey and colleagues (2004), the risks of neonatal death for first- and second- born are similar. The NMR in the United States has fallen drastically from 15.1 in 1970 to 4.54 deaths per 1,000 live births in 2004. Birth weight is used as the most significant indicator/predictor of morbidity and mortality for a neonate.

Race and ethnic disparities persist among racial groups in the neonatal period as well. The overall rate in 2004 was 4.54, but here is a more detailed breakdown: 3.78 for Mexican, 5.95 for Puerto Rican, 3.05 for Cuban, 3.23 for Central and South American, 4.31 for other unknown Hispanic, 3.71 for non-Hispanic white, and 9.13 for non-Hispanic black (MacDorman and Mathews 2008).

Demographers stratify medical disparities in neonatal mortality into two components: disparities in birth weight-specific mortality; and disparities in birth weight distribution. Birth weight is used to reflect intrauterine growth resulting in elasticity between birth weight and gestational age. If an infant is "small for gestational age" or suffers from "intrauterine growth retardation," the infant may end up having a low birth weight (Wise, 2003). There is a dramatic contribution of premature infants by the black population. The black community contributes many of the premature births occurring around 25 to 26 weeks gestational age.

There has been a dramatic decline in the NMR due to weight-specific mortality rates whereby almost 80 percent of the disparity is due to births of less than 750 grams. This decline is tied to technical strides in obstetrics, neonatal intensive care, and policies that provide healthcare access to disadvantaged groups.

Postneonatal mortality refers to deaths to infants of the age of 28 days through 364 days. Regarding overall mortality, many scholars have noted that postneonatal mortality has remained relatively unchanged over the recent past (Moss et al. 2002). The reason for separating neonatal and postneonatal mortality is because most deaths occurring to neonates tend to be associated with events surrounding the prenatal period and delivery, whereas postneonatal deaths are more likely to be associated with conditions that arise after the delivery or exogenous factors. The delivery of preterm infants is often caused by conditions arising during the antepartum and intrapartum periods, but deaths due to prematurity may be postponed to the postneonatal period (Buehler et al. 1985; Friede et al. 1988).

Frisbie (2006) notes that the reason for the virtually unchanged PNMR is due to the fact that endogenous conditions are now the most prevalent cause of death during the postneonatal period and because "advances in perinatal care and extraordinary medical intervention… have resulted in the survival of nonviable infants past the first 27 days of life," (Frisbie, Forbes, and Rogers 1992:544).

Race and ethnic disparities persist among racial groups in the postneonatal period as well. The overall rate was 2.32 but the following is a more detailed breakdown: 1.75 for Mexican, 2.37 for Puerto Rican, 1.37 for Cuban, 1.46for Central and South American, 2.14 for other unknown Hispanic, 2.05 for non-Hispanic white, and 4.50 for non-Hispanic black (MacDorman and Mathews 2008).

Finally, racial disparities for infant mortality persist. The overall IMR in 2005 was 6.86, and rates for specific groups are as follows: total Hispanic IMR, 5.62; and

Mexicans, 5.53, Puerto Rican, 8.30, Cubans, 4.42, Central and South Americans, 4.68, other Hispanics, 6.43, non-Hispanic Whites, 5.76 and non-Hispanic blacks, 13.63 (MacDorman and Mathews 2008).

The infant mortality rate among twins in 2005 was 29.84, and among triplets it was 59.6 (MacDorman and Mathews 2008). In 2005, 3 percent of all births were multiples but these 3 percent accounted for 15 percent of all infant deaths (MacDorman and Mathews 2008).

**Race and Socioeconomic Class**

As demonstrated in the race and ethnic breakdown of the rates of death shown in the above section, the disparities among fetal and infant death are large for race and ethnic groups. The gap may be narrowing but the injustices are still pervasive, which accounts in part for why race and ethnicity are important variables in this dissertation.

Demographers generally agree that higher socioeconomic status of an individual and / or community is associated with lower overall mortality, irrespective of whether SES is measured with income, occupation or education (Stockwell et al. 1978). This inverse association is found in United States data from the earliest times to the present, as well as in the data of most other countries (Rogers et al, 2000; Krieger et al., 1993; Williams and Collins, 1995).

During the early 19th Century, French public health reformers, most notably Louis Rene Villerme, used health data to study social problems such as crime and poverty. He compared data from various districts in Paris in 1822 and discovered a relationship between average income and mortality rates. He confirmed the positive association between poverty and poverty during the 1832 cholera epidemic when he contrasted rates among boarding houses that catered to different social classes (Brosco 1999). Wise (2003) notes that infant mortality implies tragedy and poor social conditions, which influence the IMR positively, and are unjust. Technical and social interpretations characterize the analysis of and response to disparities in infant mortality. Also, social forces and technical capacity have to intervene to determine disparities in infant mortality. Societal inequity is a social problem, and infant death is a biological event.

Racial disparities, although controversial regarding its use as a social indicator by non-sociologists, are often studied because race and ethnic differences "reflect the status at one point in time of a population defined by that combination of physical, historical, and cultural attributes commonly referred to as race" (Van Den Oord and Rowe, 2000: 286). According to Frisbie, "for demography, the basic substantive foci are (1) specification of the demographic, social, economic, cultural, and biomedical covariates responsible for race/ethnic inequalities in pregnancy outcomes and (2) the interpretation of race/ethnic differences that persist in the face of numerous controls for potentially confounding covariates" (2006: 255).

The Hispanic Infant Mortality Rate is interesting because it is sometimes viewed as a paradox, referred to as the Hispanic Paradox or the Epidemiological Paradox. Researchers expect the Hispanic infant mortality rate to be higher than that of whites because, generally, Hispanic people have lower socioeconomic status than non-Hispanic whites. The literature focusing on the relationship between socioeconomic status and health and mortality consistently shows that low socioeconomic status is significantly associated with poor health and mortality outcomes among both non-Hispanic whites and blacks in the United States (Sorlie et al., 1995).

Not only does the Hispanic Paradox challenge the notion that socioeconomic status is a good indicator of health but it is logically unsound. For example, Hispanics are 1.5 to 3 times less likely to complete high school than non-Hispanic whites and blacks (Singh and Yu 1996). They are also more likely to postpone prenatal care until the third trimester or to have no prenatal care at all. Rates of teenage and unwed mothers are 1.5 to 2 times higher than non-Hispanic whites (Leslie et al. 2003). Hispanics are more likely to live in poverty, 21.4% vs. 7.8% for non-Hispanic whites in 2002 (Ramirez and de la Cruz 2003). However, Kerr, Ying, and Spears (1995) write that the infant mortality rate for Hispanics has repeatedly been found to be half that of blacks and very similar to that of whites.

Many studies have found varying evidence of the Hispanic Paradox at the individual level (Hummer et al, 2007; Hummer et al. 2004; Palloni and Arias, 2004; Frisbie and Song, 2003; Leslie et al. 2003; Mathews, Manacker and MacDorman, 2003; Palloni and Morenoff, 2001; Landale, Oropesa, and Gorman, 2000; Abraido- Lanza, Dohrenwend, and Ng-Mak, 1999; Cervantes, Keith, and Wyshak, 1999; Hummer et al. 1999; Landale et al, 1999; Liao et al., 1998; LeClere, Rogers, and Peters, 1997; Singh and Yu, 1996; Sorlie et al. 1993; Sorlie, Backlund, and Keller, 1995; Buchanan and Weiss, 1995; Kerr, Ying, and Spears, 1995; Hummer et al, 1992; Becerra 1991) . Studies using various data sources including national and state vital statistics, local surveys and national linked data files, have all found varying support for the Hispanic Paradox. In general, after controlling for socioeconomic status in a multivariate analysis of infant mortality for Hispanics and non-Hispanic whites, Hispanics, as a whole, are shown to fare better in all-cause mortality than non-Hispanic whites.

One Hispanic subgroup that is positively affected are Mexican-origin persons living in the United States. This group is characterized by low educational attainment and low health insurance coverage rates (Elo et al. 2004; Frisbie and Song 2003; Hummer, Benjamins, and Rogers 2004; Lio et al. 1998; Rogers, Hummer, and Nam 2000. Several studies indicate that the similar infant mortality rate for the Mexican origin population and the non-Hispanic white population is attributable, in part, to the low mortality of the Mexican-origin immigrant population (Palloni and Arias, 2000). The United States-born Mexican-origin population experiences modestly higher death rates than the non-Hispanic white population, but lower death rates than the non-Hispanic black population (Elo and Preston 1997; Hummer, Biegler, et al. 1999; Hummer, Rogers et al. 1999; Palloni and Arias 2004).

Singh and Stella (1996) studied the differentials between United States-born and foreign-born mothers regarding infant mortality and other outcomes for several ethnic groups, including Mexicans and Puerto Ricans. These authors used the National Linked Birth and Infant Death data sets for the 1985, 1986, and 1987 birth cohorts as well as the 1988 National Maternal and Infant Health Survey and 1992 birth certificate data tapes. They found that foreign-born mothers had lower infant mortality rates than United States-born women for all race/ethnic groups except for Central and South Americans.

The authors attribute these differences to a low prevalence of teenage births, and few mothers being married to the fathers, for foreign-born mothers. Mexican women also had higher parities, with fourth- and higher order births not being unusual. The IMR is surprising given that immigrant women were also less likely to receive prenatal care in the first trimester. The authors conclude that this paradox exists because of the healthy migrant and cultural effects.

Hummer and colleagues (1999) researched the effect of nativity on infant mortality using the linked birth infant death files for 1989-91. They stated that favorable outcomes are linked to births from immigrant women compared to native-born women. Specifically, they found that infants to foreign-born women have 23 percent lower odds of mortality compared to infants of United States -born mothers. Moreover, infants of foreign-born mothers in every racial/ethnic group have lower mortality than infants of native-born mothers. The study of Hummer and colleagues replicates the findings of Singh and Yu (1996) but used data from a later data set. They show that overall infant mortality has decreased. Hummer and colleagues also used the entire United States as their study population, versus Singh and Yu who only used 23 states. The positive and significant association for foreign-born mothers and infant mortality outcomes is associated with less teenage mothers, little smoking, and more positive health profiles overall. They also note that Mexican-born women are the least likely to experience pregnancy losses or suffer medical risks during labor and delivery.

There are several hypotheses that dominate most of the literature regarding the Hispanic Paradox. In particular, there are two migration effects that consume the literature. First, the "salmon bias" explanation occurs when an immigrant returns back to the country of origin sometime after the birth of a child (Abraido-Lanza et al. 1999). Also, the "salmon bias" occurs if a woman in-migrates to the United States to have her baby, and then out-migrates to her country of origin before the baby is one year of age and the baby dies. However, due to lack of data, neither of these hypotheses can be directly tested.

Another hypothesis cited in the Hispanic Paradox literature dealing with the infant mortality rate is the "healthy migrant effect," whereby healthy migrants are selected from their country of origin for certain traits including better physical and psychological health (Abraido-Lanza et al. 1999; Palloni and Morenoff 2001; Sorlie et al. 1993). On average, migrants are healthier than those who do not migrate and may be healthier than the average individual in the receiving population. This may affect the IMR because those immigrant women having babies may be selected to be healthier than the average non-Hispanic white population. In contrast, return migrants are more likely to be in poor health than those who stay in the United States (Landale, Oropesa, and Gorman 2000; Palloni and Morenoff 2001; Palloni and Arias 2004). This may affect the adult mortality rates because an unhealthy foreign-born person may be counted in the United States Census, but then returns to his/her country of origin before death. Therefore, the person would be counted in the numerator of the mortality data but not in the denominator.

Another hypothesis presented in the literature is the cultural effect, which suggests that the Hispanic population's IMR advantage is a function of the population's social and cultural characteristics (Abraido-Lanza et al. 1999; LeClere et al. 1997; Sorlie et al. 1993). This explanation emphasizes culturally protective behaviors that may decline over time. For example, an immigrant may benefit from more healthy behaviors (i.e. less smoking and drinking), less stress, and strong family ties (Landale et al. 1999; Rumbaut and Weeks 1996. However, the more time spent in the United States, the protection incurred by immigrant status appears to decline and health worsens (Cho and Hummer 2001; Landale, Oropesa, and Gorman 2000; Rumbaut and Weeks 1996). The cultural effect would affect infant mortality outcomes by influencing individual health and lifestyle behaviors, family structure, and social networks (Palloni and Arias 2004). Therefore, if the cultural effect hypothesis is significant, we could attribute the low Hispanic infant mortality rate to the foreign-born Hispanic population's healthy behaviors such as less smoking and drinking, eating well, less stress, and social networks. Little evidence has found this hypothesis to be significant.

The last hypothesis regarding the Hispanic Paradox is what Palloni and Arias (2000) refer to as "data artifacts." They first point out the problem of underreporting of Hispanic origin on United States death certificates. This would have an effect on the vital statistics system and census population, which are the two primary sources for calculating the IMR. If a Hispanic person identifies his/her infant in the United States Census as being Hispanic, then that baby would be calculated as part of the total Hispanic population within the population. If this infant then died before reaching age 1 and the person filling out the death certificate wrote that the infant was white non-Hispanic, then the infant mortality rate for the Hispanic population would be falsely deflated. This would occur because the denominator would read that the infant was Hispanic, but the numerator would be calculated as if the infant was part of the white non-Hispanic population.

Prior to 1980, most states did not request information regarding the Hispanic-origin of the parents on birth and death certificates. Today, this information is available and researchers often use linked birth and death certificates for their studies. Prior to 1993 when all states reported Hispanic ethnicity, the Hispanic Paradox was studied by examining certificates with a Hispanic surname. This creates a problem with accuracy because not all Hispanic babies have Hispanic surnames, and not all infants with Hispanic surnames are Hispanic. However, the race and ethnicity variable in this dissertation is valid and reliable.

Finally, several studies have also focused on ethnic disparities within Hispanic subgroups. This includes Mexicans, Cubans, and Puerto Ricans (Singh and Yu 1996; Mathews, Menacker, and MacDorman 2003). Puerto Ricans have lower socioeconomic profiles, which are similar to non-Hispanic blacks (Becerra et al. 1991), while Cubans and non-Hispanic whites do not differ significantly from one another (Frisbie and Song 2003). Puerto Ricans may face the highest risk of infant mortality, while Mexicans and Cubans have lower risks; these are similar to the IMRs for the white non-Hispanic population (Hummer, Eberstein and Nam 1992; Cervantes, Keith, and Wyshak 1999. For this reason, nativity has been shown to be significant to the IMR. Hispanic infants of foreign-born mothers seem to experience lower infant mortality than those born to Hispanic United States-born mothers (Hummer et al. 1999).

**History of the Infant Mortality Rate in the United States**

Mortality data in the United States were limited until the mid 1800's and did not become systematically collected until 1944. Demographers believe that during the Colonial Period, the IMR was around 20 deaths per 1,000 births and the life expectancy was around 40 years (Poston, 2010). In 1850, "improvements in public health and sanitation, especially better water supplies and sewage disposal," were made but death rates were still higher in urban areas where the sanitation systems were poor (Haines et al., 2007).

The IMR in 1915-1916 was over 100 deaths per 1,000 births; and dropped to 26 by 1960; 13 by 1980; 11 in 1983; and 7 in 2007 (Guyer et al. 2000). The Black IMR declined between 1983 and 2004 from 19 to 14 (US Bureau of the Census). Starting in the early 20$^{th}$ Century, mortality declined dramatically. It fell 40 percent from 1900 to 1940 with a 1 percent decline each year. During this same time, life expectancy at birth rose from 47 to 63 years due in large part to the epidemiological transition which reduced the effect of infectious diseases on infant mortality and reduction in the higher mortality rates observed in urban areas (Cutler and Miller, 2005). Other factors influencing this drastic reduction in the IMR include economic innovation and nutritional gains in the United States (Fogel 1994; McKeown, 1976) as well as individually improved hygiene, i.e., hand and foot washing, the boiling of milk and breastfeeding (Ewbank and Preston, 1990), education (Deaton and Paxson, 2001; Elo and Preston, 1996), and large-scale public health innovations such as clean water, sanitation, refuse management, milk pasteurization, and meat inspection (Condran and Crimmins-Gardner, 1978; Meeker, 1972, Preston and Haines, 1991).

During the $19^{th}$ Century, many analyses of infant mortality were based on burial records and calculated as a percentage of total deaths in a community. The problem with the accuracy of this method is that child and infant mortality fluctuated with the health of the adult population. Also during this time, there were large-scale efforts to secure the health of children. This time was seen as the Progressive Era because it was characterized by a widely shared faith that science, efficiency, and cooperation could solve society's problems. Coalitions of public health officials, lay people, and politicians campaigned for labor laws, compulsory education, juvenile court systems, orphanages, and children's hospitals (Brosco, 1999). The American Association for Study and Prevention of Infant Mortality was created in 1909. The mission of this group was to improve methods of baby-saving, help local associations, and bring the IMR to national attention. Through the 1920's, the association's most influential research was a series of detailed studies of the causes of infant mortality. Public health officials noticed the need for accurate determinations of the IMR and vital statistics, which would systematically record births. Although determining the root cause of an infant death was difficult, several variables were suggested such as diet, heat, overcrowding, dirt, swaddling, heredity, fresh air, light, ignorance, and medical care (Brosco, 1999).

Many American health workers believed that diarrhea was a major cause of infant mortality. Brosco wrote that that when gastroenteritis reached its peak in the summer months, so did the number of diarrhea cases (1999). Diarrhea was responsible for one-third of the IMR but few really understood why this was so. This led doctors to start recommend breastfeeding. In 1920, J.P. Crozer Griffith stated that “we may then assume it proved, beyond question, that the absence of breastfeeding is perhaps the chief cause of infantile mortality” (1912: 59). Pediatrics emerged as a specialty in the late 19th century because of complications with breastfeeding (Cone, 1979: Jones, 1983). At the same time, public health officials started to improve the milk supply by setting standards and testing and, in 1920, pasteurization of the milk supply was implemented. When the influence of breastfeeding became evident, blame shifted from community health problems to the fault of mothers. “Some physicians called for legislation to prohibit the sale of commercial baby foods and to sanction mothers who did not nurse their children” (Griffith, 1912). Some medical professionals, including Griffith (1912), stated that poverty was more significant to infant mortality than laziness, and it was ignorance that led mothers not to breastfeed.

In 1920, a crusade for health education started whereby nurses, doctors, health stations, and health centers tried to educate mothers regarding breastfeeding and good parenting techniques. However, a gap in SES was still evident (Brosco 1999). Some mothers were unable to breastfeed because they had to work. An effort to bridge the SES gap occurred among local governments; they tried to implement day nurseries, provide health insurance for the poor, and give food, clothing, and housing to pregnant women. However, the debate always returned to blaming individuals for their being in poverty. Katz (1986) reports that many believed “ignorance, sloth, and lack of thrift caused poverty, not deficiencies in the economic or political system.”

In the early part of the 20th Century, neonatal mortality, which public health officials deemed to be due to prenatal care, started to decline. J. Whitridge Williams, Professor of Obstetrics at Johns Hopkins, wrote in an influential paper in 1915 that fetal mortality “might have been reduced 40 percent had it been possible for all our patients to have the advantages of prenatal care [and] ideal obstetrical care in the hospital” (Williams, 1915). Over time, medical interventions seemed more important than educating mothers.

Brosco (1999) notes that the early 20th century was an era of significant growth in child health and welfare efforts through a national campaign to reduce infant mortality through the US Children’s Bureau, which was founded in 1912. State and local governments focused on resources for mothers and children, and there was an increase in the numbers of pediatricians and children’s hospitals for the healthcare of children.

In the early part of the last century the American Eugenics movement was popular. This movement sought to limit proliferation of the genetically unfit, which led to a program of sterilization and immigration restriction laws (Pernick, 1996; Ludmerer, 1972). Thankfully, this movement lost its momentum.

**Conclusion**

The hazard of infant death for twins, triplets, and quadruplets is 12 times higher than that for singletons (Hoyert et al, 2006). Mathews and MacDorman (2007) wrote that twins are 5 times, and triplets nearly 15 times, more likely than singletons to die within a month of birth. The most aggressive variables having an effect on infant mortality for multiples are low birthweight (LBW) and preterm birth. Birth weight is considered to be low if the infant weighs less than 5 ½ pounds, i.e., 2,500 grams. According to Hoyert et al. (2006), the risk for LBW for infants born as twins exceeds 57 percent and the risk for very LBW is 9 percent. Blondel and colleagues (2002) argued that the increase in rates of multiple births, and not changes in the LBW rate among multiple births, contributes to an increase in the overall LBW rate. However, it cannot be disputed that multiples are at an increased risk of LBW. About half of the twins and almost all higher-order multiples are born with LBW. LBW, especially for infants born before 32 weeks gestation and/or weighing less than 3 1/3 pounds, i.e.., 1,500 grams, are at increased risk of health problems including problems in the newborn period as well as lasting disabilities, such as mental retardation, cerebral palsy, and vision and hearing loss (Wright et al. 2006). According to Blondel and associates (2002), in the U.S. between 1981 and 1997, LBW has increased by 21 percent which is similar to trends in Canada, England, and Wales.

Many authors have contributed to the literature regarding the factors that may cause LBW in both singletons and multiples. McCormick (1985) noted that smoking behavior of the mother was a large contributor to low birth weight and, thus, to infant mortality and childhood morbidity. Heffner (1999) argued that LBW, preterm births and intrauterine growth retardation are all related to maternal smoking. Other factors in LBW include poverty (Kramer, 1987), ART (Friedler et al. 1994) and maternal age, (Blondel et al. 2002).

The other major factor contributing to the infant mortality rate of multiples is preterm birth. A birth is considered to be preterm if the infant is born before 37 weeks gestation. The risk of preterm birth for twins exceeds 57 percent. According to Blondel and associates (2002), the number of preterm newborns increased in the U.S., Canada, England, and Wales between 1981 and 1997. However, the differences between the actual and expected rates show that in the U.S., Canada, England, and Wales, the effect of the increase of twins and triplets was similar to the effect of the increase in the preterm delivery rates in multiple births (Blondel et al. 2002).

More than 50 percent of twins, more than 90 percent of triplets, and virtually all quadruplets and higher-order multiples are born preterm (Hoyert el al. 2006). To be considered full-term, the gestation period must last 39-40 weeks for singletons, 35 weeks for twins, 33 weeks for triplets, and 29 weeks for quadruplets (American Society for Reproductive Medicine, 2004).

According to the American College of Obstetricians and Gynecologists (ACOG), women expecting twins are more than twice as likely as women with a singleton pregnancy to develop preeclampsia which is characterized by high blood pressure and protein in the urine (ACOG 2004). Severe cases can be dangerous for both the mother and the baby. Preeclampsia may contribute to preterm delivery because, in certain cases, the baby may be delivered prematurely in order to prevent serious complications.

Women carrying multiples are more likely to develop gestational diabetes which is a pregnancy-related form of diabetes characterized by the mother having high blood sugar (ACOG 2004). Gestational diabetes can cause a baby to grow very large which increases injuries during vaginal delivery. Babies born to mothers with gestational diabetes are more likely to have breathing problems during the newborn period.

Identical twins are also susceptible to the twin-twin transfusion syndrome. Fox and associates (2005) state that 20 percent of identical twins who share a placenta develop the twin-twin transfusion syndrome. This syndrome is characterized by a connection between the two babies' blood vessels in the placenta, whereby one baby gets too much blood flow and the other too little. Treatments have now been developed which improve blood flow to the placenta and reduces the risk of preterm birth.

Fetal and infant mortality is widely studied for the many reasons mentioned earlier in this chapter, including the emotional impact of such a tragic event, and racial disparities. My primary purpose in studying this particular group actually lies in my fascination of how mortality rates, particularly infant mortality rates, are used as an indicator of the social development, health, and advancement of a population. Populations with lower rates are considered to be more advanced and healthier than those with higher rates (Frisbie, 2006: 251). However, mortality among such sensitive subgroups as twins and triplets may not be an appropriate proxy for development due to the type of population experiencing twin and triplet births. Mothers of twins and triplets tend to be older, more educated, and wealthier. Therefore, utilizing our current standard of high IMRs indicating lower socioeconomic levels, for this particular subgroup would falsely inflate our numbers, which would, in turn, be misleading. IMRs for this subgroup do not represent an appropriate indicator of the socioeconomic level of a population. It is possible that the United States could see a substantial increase in the IMR for particular parts of the country that have higher proportions of multiple births.

Another contribution of my dissertation focuses on the potential future of ART in aging populations. Hoorens and colleagues from RAND Europe has indicated that utilizing Assisted Reproductive Technologies may help to mitigate the "aging problem" in some countries (2007). The study's objective was to quantify the effect of ART on fertility rates and population age structures in the United Kingdom and Denmark. The number of ART births in Denmark is reported as being three times as high as those in the United Kingdom with ART births accounting for 1.4 percent of all live births in 2002 in the United Kingdom. They showed that if "the number of ART cycles per capita in the United Kingdom were increased to the same levels as Denmark, the TFR in the UK would increase by 0.04" (RAND: 2006, 8). They stated that "this rise was found to be equivalent to that achieved by other policy interventions thought to increase fertility" (RAND: 2006, 8). Unfortunately, this study does not take into account the high level of developmental problems and the death rates of multiples, both of which tend to increase the emotional, social, and financial cost of such an intervention substantially.

Hopefully, my dissertation will illustrate the importance of truly understanding the complications with using mortality rates as indicators of a population's health and development. Moreover, there is no doubt that ART therapies will continue to flourish as women wait longer to have children and policymakers consider utilizing ART as a way to offset population problems. However, women and policy makers should be well aware of all the factors that go into utilizing such a technology.

# CHAPTER III

# DATA AND METHODS

This chapter describes the data and methods I will use to analyze the hazard of fetal, neonatal, postneonatal, and infant mortality for twins and triplets in the United States from 1995-2000. In this chapter, I first discuss the history and development of the United States Standard Certificates of Birth and Death and the Fetal Death Report. I will also discuss the source data used in the linked birth and death files in general, as well as the uniqueness of the Matched Multiple Birth File. Then, I will go on to describe my variables and detail how I plan to use Cox Proportional Hazard Modeling when testing my hypotheses. Next, I will discuss the structure of the models to be estimated in this dissertation. Then, I will present the various hypotheses. Finally, I will discuss the sample dataset to be utilized in these analyses.

## United States Standard Certificates and Reports

The 1989 United States Standard Birth Certificate, the United States Standard Death Certificate, and the Report of Fetal Death are the means by which the data have been collected that I will use in this dissertation. The official recording of births and deaths is the responsibility of the individual State or the District of Columbia in which the event occurs. Then, the Federal Government obtains these records through cooperative agreements with the states and District and consolidates them.

The United States standard certificates and reports are issued as models to use for each state and the District of Columbia in developing registration forms. However, each state may decide not to use the exact form, which will oftentimes lead to missing data problems. The standard forms are periodically reviewed to ensure that they meet the needs of the federal government. The United States standard certificates and reports are an integral part of the Vital Statistics Cooperative Program through which the National Center for Health Statistics (NCHS) obtains data to produce vital statistics.

By 1995, which was the first year for which the data for this dissertation were collected, there had previously been 11 issues of the Standard Certificate of Live birth, 10 issues of the Standard Certificate of Death, and 7 issues of the Standard Report of Fetal Death (formally known as “stillbirth”). Revisions occur due to the change in perceptions of what questions are important. According to the Centers for Disease Control (CDC), before 1937, birth and death certificates were tabulated by “place of occurrence,” but the later revisions changed this to “place of residence” which is still used today. The 1989 revision increased the number of items on the birth certificate from 42 to 71 (1197:7). The new items expanded the cause-of-death certification.

Birth certificate expansion was slow to start. Before 1930, the Standard Birth Certificate only included questions regarding place of birth, identifying information pertaining to the child, occupation of both parents, and parity of the mother. For fetal deaths, both a birth and death certificate were required, but the 1930 revision of the United States Live Birth Certificate added an item for stillbirth reporting, including information on period of gestation, cause of stillbirth, and whether the event occurred before labor or during labor. The 1939 version also added detailed information regarding the mother’s residence (CDC 1997: 7).

The most noteworthy changes for the death certificate in the first few decades included the addition in 1918 of autopsy information, a provision for information concerning injuries from external cause-of-death, the addition of the social security number and detailed information regarding place of residence of the deceased in 1939 (CDC 1997: 7). The 1949 revisions of the birth and death certificate restructured the placement of questions and included a section to be filled out by the medical provider regarding the mother's length of pregnancy, the child's "legitimacy" and weight at birth. In 1949, an item on citizenship of the deceased was also added, but was subsequently dropped in the 1989 revision.

Beginning with the 1939 revision, the birth certificate became the Standard Certificate of Live Birth, and in 1955 the Certificate of Fetal Death was required for all stillbirths. In subsequent revisions, the content of the certificate for a fetal death followed closely to the content of the birth certificate, except for the addition of sections containing cause-of-death and burial information. In the 1978 revision, the title was changed to the United States Report of Fetal Death to reflect the nature of the document as a statistical report rather than as a certificate to be filed permanently (CDC 1997:7).

In 1968, education of mother and father, date of last live birth and last fetal death, date the last normal menses began, prenatal care, complications related and not related to pregnancy, complications of labor, congenital malformations or anomalies of child, and birth injuries of the child were added to the birth certificate and the fetal death report. In the 1978 revision, the Apgar score and a question regarding whether or not the mother was married replaced the item on "legitimacy" for both the standard birth certificate and fetal death report. An item for specifying concurrent illnesses or conditions affecting pregnancy replaced the item for complications not related to pregnancy on the standard birth certificate and fetal death report (CDC 1997: 7).

In the 1989 revision, which is the version used to collect the data I will use in my dissertation, major content and format changes were made for the live birth certificate and the fetal death report. Both forms were lengthened to include detailed medical and health information about the mother and child. Checkboxes were added for these items to simplify completion of the forms, improve the quality of reporting of information, provide specific information concerning the attendant, and on the birth certificate, for information about place of birth and the certifier. This revision of the birth certificate and report of fetal death included more detailed items regarding complications of labor and/or delivery and specific congenital anomalies of the child or fetus; information on obstetric procedures; risk factors for the pregnancy; method of delivery; abnormal conditions of the newborn (only for live births); and a Hispanic identifier for mother and father. Other items were added to only the fetal death report including the occupation and business or industry in which the mother and/or father worked for the last year. Each state and the District of Columbia were expected to collect and code these items (CDC 1997: 8).

In 1989, the death certificate was enlarged to include a complete report of conditions that describe the chain of events leading to death and other significant conditions contributing to death. Detailed instructions for selected items including an example for completing the medical certification were also added.

**Data Reliability**

The first national birth and death statistics data published by the Federal Government were based on the 1850 decennial census. This trend continued until 1910 when doubt was cast regarding the reliability of the data. “It was more difficult to obtain accurate and complete registration of births than it was for deaths” (CDC 1997: 8). In 1915, the national birth-registration was established and by 1933, all states were included with Alaska joining in 1959 and Hawaii in 1960, which were the years in which they gained statehood.

The National Center for Health Statistics undertakes periodic tests of birth registration completeness. Early in the 20th century, states and local areas investigated the under registration of births by comparing records of infant deaths or comparing lists of school-aged children with birth records or sending postal cards to a sample of households in the state requesting information on the birth of a child. Each state used a different methodology so findings could not be combined to provide estimates of under registration of births. After the 1940 decennial census, the United States Census Bureau, the States, and independent city registration offices were able to complete valid estimates. Percent estimates of the completeness of birth registration in the United States, by state, county, and incorporated city or urban place having a population of 10,000 or more in 1940 were provided. These tests showed that birth certificates were on file for more than 99 percent of the children born between the years 1964 and 1968 (CDC 1997: 11).

The NCHS has a mission "to provide statistical information that will guide actions and policies to improve the health of the American people. As the Nation's principal health statistics agency, NCHS leads the way with accurate, relevant, and timely data" (http://www.cdc.gov/nchs/about/mission.htm, 2009). In order to ensure the accuracy of vital records for each State and the District of Columbia, the NCHS issues instruction manuals to define the general duties and responsibilities of individuals and institutions involved in the registration process (CDC 1997: 11). These manuals "provide detailed guidelines for query programs and set forth the principles and procedures essential for complete and accurate registration of vital events" (CDC 1997: 11). Cause-of-Death manuals are also provided to help with this process. Sometimes, the vital statistics offices must go to the certifying physician when additional information is needed "to clarify illegible, incomplete, imprecise, or questionable entries: to verify causes attributed to diseases that pose series threats to the health of others; and to facilitate classification of the causes in a manner that ensures the quality of cause-of-death statistics" (CDC: 1997 11).

During World Ward II, there was great concern over the reliability of mortality estimates because of the threat of epidemics and the decline in national health resulting from wartime living conditions. For example, large numbers of young people lived in close-quartered living facilities, housing was overcrowded in cities, people worked longer hours, and hospitals had a shortage of physicians. This provided an urgent need for up-to-date mortality data. Census Bureau officials, specifically Theodore D. Woolsey and Edward Deming, set up a program for taking a monthly 10-percent sample of all death certificates received in the state vital statistics offices; this survey is now called the Current Mortality Sample. The Bureau of the Census's sampling program was designed so that mortality statistics could be compiled monthly with only a 2-month delay between an individual's death and its inclusion in the statistics. Funeral directors or medical examiner/coroners were required to provide a death certificate to the local registrar who then sent the death certificate to the state central vital statistics office. Then, states would send monthly samples to the national office. The first release date was February 5, 1943. Today, monthly mortality statistics based on the 10-percent mortality sample are published by NCHS in the *Monthly Vital Statistics Report* (MVSR). These reports allow for the confirmation of the trends that are shown in the data in this dissertation.

**The Source Data**

The data to be used in my dissertation were extracted from the Vital Statistics Program's birth and death records through the Centers for Disease Control's (CDC) National Center for Health Statistics (NCHS). Each model for this dissertation will be estimated using one of four different timing variables, namely, the fetal period, neonatal period, postneonatal period, and infant period (Table 3.1). The mortality outcomes will be examined relative to several independent variables including plurality (for the model controlling for plurality), birthweight, gestational age, race or ethnicity of the mother, age of mother, parity of mother, sex of the child, and birth order of the child.

The NCHS undertook, in the early 1990s, their first effort to create a national file of linked birth and infant death records for the birth cohort of 1960. The 1995 dataset was the first linked dataset that provided period data versus cohort data. These data were provided based on of the year of death of the infant, not the year of birth. This change allowed for the more timely release of data.

The data from the Matched Multiple Birth File were developed in order to allow researchers to analyze the characteristics of sets of births and fetal deaths in multiple deliveries. This type of analysis is not possible using the NCHS Live Birth and Fetal Death Files because these files contain individual records of births and deaths in multiple deliveries, but do not identify set members. Thus, specific variables for a multiple set are not available. The Matched Multiple Birth file matches members of multiple deliveries to their twin or triplet brothers or sisters. Then, they link these birth certificates to death certificates, if there were deaths that actually occurred. To match the members of a multiple set, NCHS first identified all records reported as multiple births in the restricted-use United States Live Birth and Fetal Death Files for 1995-1998. All live birth and fetal records with reported pluralities of 2 or greater were selected for matching. The data from the Linked Live Birth / Infant Death Cohort Data Sets for 1995-1998 were also utilized in order to identify infant deaths of up to one year of age. NCHS was able to match 98.1 percent of the records. For this dissertation, only the twin and triplet records will be analyzed.

One of the important features of these data is that the classification of a multiple set that is diagnosed at twenty weeks gestation is the same classification given to the fetus or infant for the dataset. For instance, if a set of fetuses is diagnosed as a triplet set at twenty weeks gestation, but one fetus dies at thirty weeks, all of the fetuses in that set are and will continue to be considered part of a triplet set.

**Quality of Data**

Problems with the data usually result from imperfections in the original records or from the "impracticability of tabulating these data in very detailed categories" (Vital Statistics 1998: 17). The Vital Statistics Office (1998: 17) reports that an estimated 99 percent of all births occurring in the United States were registered during the time the events in this dataset occurred. Specifically, non-Hispanic White births registration was 99.4 percent complete, and for all other births the percent complete equaled 98.6. These estimates are based on the results of the 1964-68 test of birth-registration completeness according to the place of delivery and race and on the 1989 proportions of births in these categories (Vital Statistics 1998: 17). Data for individual states are not available.

**Dependent Variables**

Within each of these hazard models to be estimated in this dissertation, I will use two types of dependent variables simultaneously, one with the prefix "death" and one with the suffix "timing." The "death" dependent variables will be a dummy variable scored 1 if the twin or triplet died, and 0 if the twin or triplet did not die during the time period being analyzed. These variables will be coded as "deathfetal" "deathneonatal" "deathpostneonatal" and "deathinfant." The second dependent variable, the "timing" variable, will include the timing of death in gestational weeks. The variables will also apply separately to the fetal, neonatal, postneonatal, and infant periods and will be coded as "fetaltiming," "neonataltiming," "postneonataltiming," and infanttiming" accordingly.

When the hazard model is estimated for the neonatal period, all fetal deaths will be dropped; for the postneonatal period all fetal and neonatal deaths will be dropped; and for the infant period, all fetal deaths will be excluded from the analysis. For the fetal period all cases will be included.

**Independent Variable, Birthweight**

Birthweight is reported in some areas in pounds and ounces rather than in grams. However, the metric system is typically utilized in published research. This dissertation will use the traditional metric system. The categories were changed in 1979 to be consistent with the recommendations in the Ninth Revision of the International Classification of Diseases (ICD-9), which defines very low birthweight as less than 1,500 grams; low birthweight as less than 2,500 grams; and 4,000 grams or more as over the optimal weight, a set of categories I also use in this dissertation. The American Academy of Pediatrics (in 1935) and The World Health Organization in the *Sixth Revision of the International Lists of Diseases and Causes of Death* define very low birthweight as 1,500 grams or less; low birthweight as 2,500 grams or less; and over optimal birthweight as 4,000 grams or less which is a 1-gram difference from the ICD-9 definition.

In my hazard models, I will enter dummy variables for very low birthweight, low birthweight, optimal birthweight, and over optimal birthweight, with optimal birthweight used as the reference group.

**Independent Variable, Period of Gestation**

The NCHS defines the period of gestation as beginning with the first day of the last normal menstrual period (LMP) and ending with the day of the birth. "The LMP is used as the initial date because it can more be accurately determined than the date of conception, which usually occurs 2 weeks after the LMP" (Vital Statistics 1998: 11).

According to the ICD-9, a birth that occurs prior to 37 completed weeks of gestation is considered to be "preterm" or "premature" for classification purposes. At 37-41 weeks, births are considered "term," and at 42 weeks or more, the fetus is considered "postterm." The American Academy of Gynecologists (ACOG) reports that prematurity is one of the most serious complications of multiple labor and delivery. Prematurity is especially dangerous because it often coincides with low birthweight. Important to note is that the full-term definition should be applied to singletons but the average twin pregnancy delivers at about 35 weeks and triplets at 33 weeks, which is consistent with the data in this dissertation. In multiple pregnancies, the rate of prematurity rises to 50 percent in twins and 90 percent in triplets (ACOG, 2004).

The 1989 version of the United States Standard Birth Certificate included "clinical estimate of gestation" as an estimate of gestational age which has not be tested for accuracy compared to the LMP estimation. The clinical estimate was used if the LMP was not reported or if both estimates were compatible, which occurred in 5.1 percent of the births in 1998.

The first trimester includes weeks one through twelve. The mother is not actually pregnant for the first two weeks, however. Since conception typically occurs about two weeks after the LMP begins, in order to calculate a due date, the health care provider typically counts ahead forty weeks from the start of the LMP. This means that the period is counted as part of the pregnancy even though the mother was not actually pregnant at the time. The second trimester includes weeks thirteen through twenty-seven, and the third trimester includes weeks twenty-eight to forty.

Because of the complications with the definition of preterm for twins and triplets and the large potential for measurement error, this variable will be measured as an interval ranging from 20 to 46 weeks gestation.

**Independent Variable, Race and/or Ethnicity**

This dissertation will focus on Non-Hispanic White, Non-Hispanic Black, and Hispanic births and deaths only. The birth certificate does not provide for reporting the race or ethnicity of the newborn. Prior to 1989, there were several different classifications for a child's race or ethnicity. When both parents were not of the same race or ethnicity, rules had been established for coding various combinations; to illustrate, if only one parent was non-Hispanic White, the child was assigned the race of the other parent; if neither parent was non-Hispanic White, the child was assigned the race of the father except if either parent was Hawaiian or part-Hawaiian. If the child was part Hawaiian, then the child's race was assigned as Hawaiian. Additional rules applied for situations where the parent's race was not stated. If race was missing from one parent, the child was assigned the race of the other parent; when race was missing for both parents, the race of the child was considered not stated.

The rule changed in the 1989 revision; now the race of the child is considered to be the race of the mother. There are several reasons why 'race of mother' has been chosen as the standard. First, the 1989 updated birth certificate included many more health questions that are directly associated with the mother; also, other items that had been on the birth certificate for decades also pertain to the mother. The second factor was the increasing incidence of interracial parentage (DHH 2000:5). In 1998, 5.3 percent of births were to parents of different races. Another factor included the growing proportion of births with "fathers not stated," which equaled 14 percent in 1998. For the data in this dissertation, natality tabulations were modified to show race of the mother, rather than the imputed race of the child.

In the 1980's Hispanic-origin data became of interest which resulted in a Hispanic-origin question in the 1989 revision. A general ancestry question was offered as an option for those states without a large Hispanic population in order to justify the specific question or for those that may have a need for data on other segments of their population (CDC 1997: 16). The 1989 revision of the standard certificates and Fetal Death Report has an item requesting a "yes" or "no" answer for Hispanic origin. If the mother or father answered yes then they are asked "if yes, specify". Mortality statistics for the Hispanic-origin population were published for the first time in 1984 and included data for 22 States and the District of Columbia. Natality statistics for the Hispanic-origin population were first published in 1978 data and included data for 17 states. The data used in this dissertation included all states and the District of Columbia.

I will use dummy variables in order to code the “non-Hispanic White” “non-Hispanic Black” and “Hispanic” variables. This dataset was delivered with the Hispanic variable already extracted from the “non-Hispanic White” and “non-Hispanic Black” columns. First, I will create the “Hispanic” variable where 1 will represent Hispanic mothers and 0 will represent non-Hispanic White and non-Hispanic Black mothers. Then, I will create the “non-Hispanic White” variable where 1 will represent all non-Hispanic White mothers and 0 will represent Hispanic and non-Hispanic Black mothers. Finally, I will create the “non-Hispanic Black” variable where 1 will represent the non-Hispanic Black mothers and 0 will represent non-Hispanic White and Hispanic mothers. When my models are estimated, the “non-Hispanic White” group will be the reference group.

**Independent Variable, Age of Mother**

On the 1989 revision of the birth certificate, “date of birth” of the mother was asked instead of “age” of the mother. The states of Kentucky, Nevada, North Dakota, Virginia, and Wyoming reported the “age” of mother, so the “date of birth” had to be derived. In this dissertation, the age variable will be an interval variable ranging from 15 to 50. All mothers who reported being 15 or younger are classified as “15” and mothers who reported being age 50 or older are classified as “50.”

**Independent Variable, Parity**

Parity equals the sum of live births both living and dead reported by the mother. Parity is coded as an interval variable ranging from 0 to 19, meaning that the lowest parity equals zero and the highest 19 births for a mother. A parity score equaling 0 would only occur on a fetal death record.

**Independent Variable, Male**

"Male" will be a dummy variable coded as 1 if the reported sex is male and 0 if the reported sex is female. All fetuses over 20 weeks gestation have a determinable sex.

**Independent Variable, Firstborn**

This dataset provides information regarding the birth order of the fetus or infant in the multiple set. Whether or not the fetus or infant is the first to be born within the set will be reported as equaling 1 if the fetus or infant is the first to be born, and 0 if not.

**Diagnostics**

In my estimation of hazard models, I will employ a set of diagnostics. Multicollinearity is an important issue I will address; it arises if one or more of the independent variables is correlated with another (Menard 1995). If two independent variables are perfectly correlated with one another, it becomes impossible to obtain an estimate of the regression coefficients separately (Menard 1995). Menard states:

As collinearity increases among the independent variables, linear and logistic regression coefficients will be unbiased, and as efficient as they can be (given the relationships among the independent variables), but the standard errors for linear and logistic regression coefficients will tend to be large (1995: 65).

In order to test for multicollinearity, I will calculate tolerance statistics for each of the independent variables in the model. I will use a tolerance value of .40 or higher to indicate that there is not a troublesome amount of collinearity associated with the independent variable; a tolerance value of .40 indicates that 40 percent of its variance is independent of that of all the other independent variables in the equation. I will use this .40 as the cut off point; although statisticians do not agree about the minimum tolerance, a value of .40 seems to be reasonable.

Before estimating a hazard model, I will describe the dependent variable, the hazard, by producing a Kaplan-Meier Survival Estimate curve; this will allow me to visually inspect the data. After I have inspected the dependent variable data, I will estimate the model.

**Cox Proportional Hazard Method**

I will estimate my hazard models using Cox Proportional Hazard models, which are based on a partial likelihood estimation method. One advantage of the partial likelihood estimation method over a maximum likelihood method is that the models can assume time dependence without having to specify its form. The equation is represented as follows:

$$\log h(t) = a(t) + b_1X_1 + b_2X_2$$

where a(t) is any function of time. The proportional hazards model assumes that hazard rates are a log-linear function of the parameters for the effects of the co-variates. The value for person **i** at time **t** is denoted by $h_i(t)$ and is written as follows:

$$h_i(t) = h_0(t) \exp [\Sigma\, b_k\, X_{ik}\,(t)]$$

where $h_0(t)$, represents the major dimension of time dependence and is called the baseline hazard function, and $X_{ik}\,(t)$ is the value of the $k^{th}$ co-variate for subject i at time t. The partial likelihood estimates of parameters are obtained by maximizing the partial likelihood function. The partial likelihood function is based on length of duration, and subjects are ordered from the smallest to the largest duration. The subscript i in the formula below indicates the $i^{th}$ subject after the ordering is made. Then the partial likelihood function is:

$$PL = \prod_{i=1}^{i} [h_i(t_i) / \sum_{j \geq i} h_j(t_i)]^{\delta_i}$$

where $h_j(t_i)$ is the value of the hazard function for the $j^{th}$ subject at time $t_i$, $t_i$ is the time at which the $i^{th}$ subject had either experienced the event or been censored, and $\delta_i$ is a dummy variable that takes the value of 1 when the $i^{th}$ subject had an event and 0 if the $i^{th}$ observation was censored.

When the two above equations are combined, the baseline hazard function $\mathbf{h_0(t)}$ is canceled out between the numerator and the denominator. Thus the partial likelihood function is written as a function of parameters for the co-variates, such as

$$PL = \prod_{i=1}^{I} \{\exp[\sum_k b_k X_{ik}(t_i)] / \sum_{j \geq i} \exp[\sum_k b_k X_{jk}(t_i)]\}^{\delta_i}$$

The above implies that although the presence of a baseline hazard function that reflects the time dependence of hazard rates is assumed in the Cox Proportional Hazard Model, when the model is actually estimated via the partial likelihood method, its functional form need not be specified.

After the data are cleaned and I estimate my models, I will report both the hazard coefficients and the hazard ratios. The hazard ratios are more easily interpreted than the coefficients. By multiplying the result of "1 minus the hazard ratio" by 100, I am able to see the percent change in the hazard due to a unit change in the independent variable. In the final model in each analysis, I will also re-scale the hazard coefficients by multiplying them by their standard deviations; this will enable me to compare within an equation the relative effects of the independent variables on the hazard being estimated.

**Model Structure**

Three series of Cox Proportional Hazard models will be estimated for each of the four timing period, namely, the fetal, neonatal, postneonatal, and infant periods (see Table 3.1). The three series of models will be labeled "Twins-Only Series," "Triplets-Only Series," and "Twins and Triplets Series." Each series will consist of four separate models.. The first model will include the birthweight and gestational age variables; the second will include the variables in the first model plus race, ethnicity, age of the mother, and parity of the mother ; the third model, also called the "inclusive model", will include the variables of the first two models, plus the sex of fetus and the birth order variables; the fourth model, which is really comprised of the results of the third model reported in a different way, will show the semi-standardized hazard ratios based on the inclusive model; the results in this model will enable me to compare the relative effect of each independent variable on the likelihood of the hazard. For the Twins and Triplets series, each of the models will be run with a control for plurality. Overall, for each timing period (fetal, neonatal, postneonatal, and infant), results for three series of four models each will be shown, equaling a total of 48 models. Chapters IV through VIII will include 12 models each (See Table 3.1).

**Hypothesis**

Each of the independent variables I include in my hazard models has its own separate hypothesis with no difference in direction expected for twins and triplets. However, I do expect that in the analyses of triplets, the X variables will have stronger effects that they will have in the analyses of twins.

I hypothesize that a fetus or infant of very low birthweight (less than 1,500 grams) will have a higher risk of suffering the hazard of death than a fetus or infant of optimal birth weight (2,500-4,000 grams); also, a fetus or infant of low birthweight (1,500 through 2,499 grams) will have a higher risk than a fetus or infant of optimal birthweight; and a fetus or infant weighing over the optimal birthweight (4,000 grams and more) will have a higher risk than a fetus or infant of optimal birthweight. I hypothesize that this hazard will decrease in intensity progressively from the fetal period to the postneonatal period. Specifically, birthweight will have less of an effect on the hazard of dying by the time the child reaches the postneonatal period.

I also hypothesize that a fetus or infant labeled as Hispanic ethnicity will have a higher risk of death than a fetus or infant labeled as non-Hispanic White; and a fetus or infant labeled as non-Hispanic Black will have a higher risk of death than a fetus or infant labeled as non-Hispanic White. I expect that there will be no difference between twins or triplets with respect to the effect for this variable, and that the impact of the time period will also not change throughout the analysis.

Next, I expect that as the mother's age increases, the hazard of death will also increase. I hypothesize that there will be no difference between twins and triplets with respect to the effect of mother's age, and that the impact of the time period will also not change throughout the analysis. Also, as parity increases, I expect the hazard of death will decrease. Again, I do not expect the effect of parity to be significantly different for twins and triplets. However, I do expect the impact of this variable to decrease in intensity as the analysis moves from the fetal to the postneonatal period.

As reported in the literature, I expect that a male fetus or infant will have a higher hazard of death than a female fetus or infant. The impact of this variable should not be different for twins or triplets but the size of its effect should increase as the analysis moves from the fetal to the postneonatal period. Similarly, I expect that a first-born fetus or infant will be less likely to suffer the hazard of death than a second- or third- born fetus or infant. I expect that this variable will have a similar effect in each of the time periods but will have a stronger effect on the hazard of dying for a triplet than for a twin.

**Dataset**

The dataset I will use in my dissertation is comprised of data produced by a matching of the birth certificate of a fetus or infant to the birth certificates of its siblings within the multiple set. I should not use every case in this set because each fetus or infant within the multiple set will have experienced the same prenatal and postnatal environment. In order to remedy this problem, I ran the "sample" command in STATA, which randomly drops all but one record for each multiple set. This produces a dataset with 313,770 randomly selected cases. In order to show the differences in the calculations between using the full dataset and the randomly selected dataset, I show in

Tables 3.2 through 3.5 the percent changes in the hazard of dying for the inclusive model (Model 3) within each series. In general, the results are very similar with the biggest differences occurring with the birthweight variables. The main reason for any difference between the full dataset and the sample dataset is the shear increase in the number of records analyzed and the correlation between records. Therefore, I will use the random sample so that I can meet the independence assumption.

**Conclusion**

In this chapter I have shown that the reliability of the data I will use in my dissertation is very strong which allows me to have confidence moving forward with the data analysis. Even though the United States Standard Birth and Death Certificate for 1989 and Fetal Death Report provided a wealth of data, only variables without missing data were utilized. A sensitivity analysis was performed and provided information regarding the importance of only utilizing complete variables.

In this chapter I discussed the history and development of the United States Standard Certificates of Birth and Death and the Fetal Death Report. I next discussed the linked birth and death files in general as well as the uniqueness of the Matched Multiple Birth File. Then, I described the coding of my variables and detailed how I plan to use Cox Proportional Hazard Modeling. I then explained the structure of the models to be estimated and specified each of my hypotheses. Finally, I explained the importance of utilizing a randomly drawn subset of data created from the full dataset. Next, I turn to Chapter IV, which will lay out the models in the Twins-Only, Triplets-Only, and Twins and Triplets series for the hazard of dying within the fetal period.

# CHAPTER IV

# ANALYSIS OF FETAL MORTALITY

Chapters IV, V, VI, and VII report the results of my dissertation. Each follows the same structure and format. Each starts with a description of the data for the time period analyzed, with Chapter IV focusing on the fetal period, Chapter V on the neonatal period, Chapter VI on the postneonatal period, and Chapter VII on the entire infant period. After presenting a description of the data, the results from the Cox Proportional Hazard models will be shown for three separate series of models. The first series will provide analysis for only twins; the second for only triplets; and the third for both twins and triplets, with a control for plurality. Then, I will interpret the results of the models for the three series used to investigate mortality within the timing period. I now move to a description of the dataset.

## Descriptive Statistics

In this dataset there are 302,443 twins and 11,337 triplets. Of these, 2,053 twin and 99 triplet fetuses experienced fetal death, and 300,380 twins and 11,238 triplets survived the fetal period and were born alive.

In Chapter III, I showed the operationalization of the independent variables. In this chapter I will describe each variable. The first model in each of the three series of analyses undertaken in this chapter includes birthweight variables and a gestational age variable. The birthweight variables for the fetus are separate dummy variables regarding whether or not the fetus was assigned a birthweight of under 1,500 grams (very low birthweight), 1,500 to 2,499 grams (low birthweight), 2,500 to 3,999 grams (optimal birthweight), or 4,000 grams or more (over optimal birthweight). The birthweight information for each fetus is the number of grams the fetus weighed at live birth or at fetal death. The other major variable in this model is an interval variable measuring the gestational age of the fetus when it experienced live birth or fetal death. The range spans 20 to 47 weeks of gestation.

For the birthweight variables, there are 1,776 fetuses (1,688 twin and 88 triplet fetuses) that experienced fetal death at the weight of less than 1,500 grams, which is considered to be a very low birthweight; this comprises 82.5 percent of all fetal deaths. In contrast, of the fetuses who were eventually born (and did not experience fetal death), 10.9 percent of them weighed less than 1,500 grams.

To continue, there are 269 twin and 8 triplet fetuses that experienced fetal death at a weight of 1,500-2,499 grams, which is considered low birthweight; they comprise 12.9 percent of all fetal deaths. By comparison, 44.4 percent of fetuses that were born alive weighed between 1,500 and 2,499 grams. There are 93 twin and 3 triplet fetuses that experienced death during the fetal period weighing what is considered optimal weight, between 2,500 and 3,999 grams; this comprises only 4.5 percent of all fetal deaths. Of the fetuses born alive, 44.5 percent of them had this weight. Finally, there are 3 twin and no triplet fetuses that experienced death during the fetal period and weighed over 4,000 grams, which is considered to be “over optimal weight”; this is a small 0.1 percent of all fetal deaths; the same very small percentage of fetuses who were born alive weighed over 4,000 grams (See Table 4.1).

The next variable is gestational age and ranges from 20 to 47 weeks. The mean gestational age for the sample of twins is 35 weeks (Table 4.2) and 32 for triplets (Table 4.3). The mean gestational age for fetuses that experienced fetal death is 27 weeks for twins and 26 weeks for triplets. In contrast, the mean gestational age for fetuses not experiencing fetal death is 36 weeks for twins and 32 weeks for triplets (see also Tables 4.2 and 4.3).

The second model within each series adds variables pertaining to the mother's characteristics. For the analyses including only twins, 68 percent of the twins have mothers who are non-Hispanic White; 14 percent of the twins have mothers who are Hispanic; and 18 percent of the twins have mothers who are non-Hispanic Black. On the other hand, 85 percent of triplets have mothers who are non-Hispanic White; 8 percents of triplets have mothers who are Hispanic; and 8 percent of triplets have mothers who are non-Hispanic Black.

The average age for mothers of twins is 29 years (Table 4.2) and for mothers of triplets the average age is 32 (Table 4.3). Of the fetuses that experienced fetal death, the average age of the mother is 27 for twins (Table 4.2) and 30 for triplets (Table 4.3). Of the fetuses that survived the hazard of fetal death, the average age of the mother is 29 for twins (Table 4.2) and 32 for triplets (Table 4.3). This is, on average, a difference of two years for mothers who had a fetus survive versus mothers who had a fetus that died.

The final variable dealing with characteristics of the mother is her parity. Parity in this sample ranges from 0 to 19. The average parities for mothers of twins and mothers of triplets are 2.5 and 3, respectively (see Figure 4.1). Of the fetuses that experienced the hazard of death during the fetal period, the average parity for the mother is 1.25 for twins and 1.36 for triplets. In contrast, of the fetuses that survived the hazard of fetal death, the average parity for the mother is 2.54 for twins and 2.60 for triplets. This shows that women who had 2 or more previous live births are less likely to have a twin or triplet suffer the hazard of fetal death than women who had between 1 and 2 previous live births.

The third model within each series adds two variables for the fetus. The first is a dummy variable indicating whether or not the fetus is a male. According to the National Center for Health Statistics, all fetuses over 20 weeks of gestational age have a known sex. In this sample, 50 percent of both the twins and triplets are females. The non-Hispanic White sex ratio is 102; the non-Hispanic Black sex ratio is 100, and the Hispanic sex ratio is 98. The percentages among the twins and triplets that died show a different trend, with more male fetuses dying than female fetuses. Specifically, 0.69 percent of male twins died while 0.66 percent of female twins died during the fetal period and 0.92 percent of male and 0.83 percent of female triplets died during the fetal period. The sex ratios are 106 for twins and 111 for triplets.

The next variable is a dummy variable that specifies whether or not the fetus was the first in the multiple set to emerge from the mother. In this sample dataset, there are 152,678 twins and 3,723 triplets that were the first to emerge from the mother. First-born fetuses compromise 50 percent of the twins and 33 percent of triplets during the fetal period. Of the twin fetuses that died, 707 (or 34.44 percent) are first-born, while 1,346 (or 65.56 percent) are second-born. For triplets, 22 or (22.22 percent) of the triplet fetal deaths are to the first-born, while 77 or (77.78 percent) of the triplet deaths occur to second- or third- born triplets. Of the twins that survived the hazard of death during the fetal period, 151,971 (or 50.59 percent) are first-born and 148,409 or (49.41 percent) are second-born. For triplets that survived 3,701 (or 32.93) are first-born and 7,537 (or 67.07) are second- or third- born.

**Description of the Dependent Variable**

In this section I describe the dependent variable, the hazard of the fetus experiencing fetal death. I do so by presenting Kaplan-Meier curves which are empirical plots showing the probabilities of surviving for each unit of time (see Figures 4.2 through 4.4). The plot steps down one week at a time from 20 weeks to 47 weeks of gestation. As expected, the probability of surviving a fetal death decreases over the gestational weeks; this may be thought of as, roughly speaking, the mirror image of the hazard.

The Kaplan-Meier Curve (see Figure 4.2) shows the survival curve for twins during the fetal period. The analysis starts at 20 weeks of gestation and all survivors (also known as live births) are censored at 48 weeks of gestation. The frequency of fetal death increases substantially from the twentieth through the twenty –fourth week then decreases consistently throughout the rest of the timing period. However, there is a small but significant increase between weeks thirty-four and thirty seven.

The next Kaplan-Meier Curve (see Figure 4.3) represents the survival plot for triplets during the fetal period. The analysis starts at 20 weeks of gestation and the survivors (or live births) are all censored by 45 weeks of gestation. The hazard of death increases each week from 20 through 23 weeks with the twenty-second week having the highest percentage of deaths (0.88 percent of triplets die during the twenty-second week). After the twenty-second week, the hazard of death for a triplet fetus decreases substantially with each week of gestation. Similar to the analysis of the hazard of fetal deaths for twins, triplet fetal deaths also experience a slight increase around weeks thirty-two and thirty-three.

The Kaplan-Meier Curve stratified for both twins and triplets during the fetal period shows that the hazard of fetal deaths for twins and triplets is different. Twins are less likely to suffer the hazard of fetal death than twins, and triplets are more likely to die earlier in the pregnancy.

**Analysis of Fetal Death for the Twins-Only Series**

I begin my hazard analysis of the twins-only data by first considering only the effects of birthweight and gestational age on the hazard of fetal death; then I add into the model the additional independent variables of mother's characteristics; then in the final model (which will be presented in Table 4.6), I add in the independent variables of sex of the fetus and whether it was firstborn.

Before undertaking the hazard regression analysis, I examined the independent variables for the presence of excessive multicollinearity. All of the independent variables in the full model have tolerances well within acceptable levels. The lowest tolerance of any of the X variables is the parity variable with a tolerance of 0.86, and the mean tolerance of the full set of X variables is .94.

The first model in the Twins-Only Series includes the birthweight variables and the gestational age variable (see Table 4.4). As noted earlier, I use four birthweight dummy variables to capture birthweight; in the hazard equations, the optimal birthweight dummy is used as the reference. Compared to optimal birthweight fetuses there is a 347 percent increase in the hazard of fetal death for very low birthweight fetuses, and a 32 percent increase for low birthweight fetuses; there is a very high percent increase for fetuses weighing 4,000 or more grams. This confirms the hypothesis that fetuses below and above the optimal birthweight will have an increased hazard of dying during the fetal period. Also, for each additional week of gestational age, there is on average a 27.3 percent decrease in the hazard of fetal death. This confirms the hypothesis that longer gestational periods tend to result in a decrease in the hazard of fetal death.

The second model in the Twins-Only Series includes, in addition to the birthweight and gestational age variables, the mother's characteristics (see Table 4.5). Compared to optimal birthweight fetuses, there is a huge effect in the hazard of fetal death for very low birthweight fetuses and also a very large increase in the hazard of death for over optimal birthweight fetuses. The low birthweight variable is no longer significant when the mother's characteristics are added to the model.

The third model in the Twins-Only Series includes the variables in Model 2 and adds the sex of fetus and birth order variables (see Table 4.6). Compared to optimal birthweight fetuses, there is a large effect on the hazard of fetal death for very low birthweight fetuses and an even larger effect in the hazard of fetal death for over optimal birthweight fetuses. Again, the low birthweight variable is not significant. For each increase in the gestational age of the fetus, there is a decrease of 24.8 percent in the hazard of fetal death. For the most part, the significant effects of my two major independent variables on the hazard of fetal death are sustained when the controls are added to the model.

The final model presents semi-standardized hazard coefficients; they enable me to compare the relative magnitude of the partial effects on the hazard of fetal death of each of the X variables. My intention here is to ascertain which of the independent variables has the greatest relative effect on the hazard of fetal death, and how the relative effects of my two key independent variables compare with those of all the control variables. The semi-standardized coefficients shown in Table 4.11 are based on the hazard coefficients shown in Table 4.10. They are calculated by multiplying the hazard coefficient of an X variable by its standard deviation; the metric for all the X variables is thus in standard deviation units.

Of all the independent variables in my model predicting the hazard of a fetal death among twins, the variable with the greatest relative effect is the parity variable. The higher the parity of the fetus, the less the hazard of a fetal death. My two key independent variables are gestational age and birthweight. The gestational age variable has the 2$^{nd}$ largest semi-standardized hazard coefficient, and the very low birthweight dummy variable has the 3$^{rd}$ highest semi-standardized hazard coefficient. I conclude that not only are these variables associated significantly with the hazard of a fetal death, they are among the three most influential of all the independent variables in my model.

Gestational age and birthweight, particularly very low birthweight, are very important predictors of the hazard of a fetal death. I next turn to my analyses of triplets.

**Analysis of Fetal Death for the Triplets-Only Series**

As in the Twins-Only Series, I begin my hazard analysis of the triplets-only data by considering only the effects of birthweight and gestational age on the hazard of fetal death; then I add into the model the additional independent variables of mother's characteristics; then in the final model (presented as Table 4.10), I add in the independent variables of sex of the fetus and whether it was firstborn.

Before the hazard regression analysis is run, independent variables are tested for multicollinearity. All of the independent variables in the full model have acceptable tolerance levels. The lowest tolerance of any of the X variables is the gestational age variable with a tolerance of 0.74, and the mean tolerance of the full set of X variables is .87.

The first model in the Triplets-Only Series includes the birthweight variables and the gestational age variable (see Table 4.10). The very low birthweight and over optimal birthweight variables are not significant in this model. However, compared to optimal birthweight fetuses there is an 87.4 percent decrease in the hazard of fetal death for low birthweight fetuses. This finding is counter to the hypothesis that fetuses below the optimal birthweight will have an increased hazard of dying during the fetal period; my analysis here shows the exact opposite. This is probably occurring due to the usually early delivery of triplet fetuses. For instance, if a fetus is experiencing problems, the doctor may deliver it early, which results in a lower birthweight for the live birth. On the other hand, for each additional week of gestational age, there is, on average, a 32.9 percent decrease in the hazard of fetal death, which confirms the hypothesis that longer gestational periods result in a decrease in the hazard of fetal death.

The second model in the Triplets-Only series includes the birthweight and gestational age variables and the mother's characteristics (see Table 4.9). Again, the very low birthweight variable and over optimal birthweight variables are not significant. However, the low birthweight variable is significant and shows that there is a 87.7 percent decrease in the hazard of fetal death for low birthweight fetuses, controlling for the other variables. This is consistent with the findings of the first model. Also, there is a 31 percent decrease in the hazard of fetal death for triplets for each week increase in gestational age, controlling for the other variables.

The third model in the Triplets-Only Series includes the variables in Model 2 and adds the sex of fetus and birth order variables (see Table 4.10). Compared to optimal birthweight fetuses, there is a 85.8 percent decrease in the hazard of fetal death for low birthweight fetuses. Again, the low birthweight variable and over optimal birthweight variables are not significant. For each increase in the gestational age of the fetus, there is a 29.7 percent decrease in the hazard of fetal death. The significant effects of birthweight and gestational age on the hazard of fetal death for triplets are sustained when the controls are added to the model.

As in the Twins-Only Series, the final model presents semi-standardized hazard coefficients (see Table 4.11), which shows the relative effects on the hazard of triplet fetal death for the X variables in the final model, and, specifically, how the relative effects of the birthweight and gestational age variables compare with the relative effects of the control variables.

Similar to the findings in the Twins-Only Series, one of the variables in the Triplets-Only Series with the greatest relative effect is the parity variable. This means that the higher the parity of the fetus, the less the hazard of a fetal death. The other variable with the greatest relative effect is the firstborn variable. Gestational age and birthweight, which are the two key independent variables, show the3rd and 4$^{th}$ greatest relative impacts. The gestational age variable has the 3$^{rd}$ largest semi-standardized hazard coefficient, and the low birthweight dummy variable has the 4$^{th}$ highest semi-standardized hazard coefficient. I conclude that not only are these variables associated significantly with the hazard of a fetal death, they are among the most influential of all the independent variables in my model. Gestational age and birthweight are very important predictors of the hazard of a triplet fetal death. I next analyze the hazard of fetal death for twins and triplets, while controlling for plurality.

**Analysis of Fetal Death for the Twins and Triplets Series**

As in the previous two Series, I begin my hazard analysis of the Twins and Triplets Series considering the effects of birthweight and gestational age on the hazard of fetal death but, in this model I add a plurality dummy variable; this allows me to control for the already demonstrated differences in fetal mortality for twins and triplets. Then, I add into the model the additional independent variables of mother's characteristics; then in the final model (which will be presented in Table 4.18), I add in the independent variables of sex of the fetus and whether it was firstborn.

The first model in the Twins and Triplets Series includes the plurality variable, birthweight variables and the gestational age variable (see Table 4.12). All of these variables except low birthweight are significant in the first model. The first variable, plurality, shows that triplets are 49.8 percent less likely to suffer the hazard of fetal death than twins. This does not confirm my hypothesis that twins should be more likely to suffer the hazard of fetal death. This may be occurring because triplets are more likely to be delivered early which results in triplets having a higher likelihood of experiencing a live birth. Compared to optimal birthweight fetuses there is a large increase in the hazard of fetal death for very low birthweight fetuses and an even larger increase for over optimal birthweight fetuses. This confirms the hypothesis that fetuses below and above the optimal birthweight will have an increased hazard of dying during the fetal period. On the other hand, for each additional week of gestational age, there is, on average, a 27.6 percent decrease in the hazard of fetal death which confirms the hypothesis that longer gestational periods result in a decrease in the hazard of fetal death.

The second model in the Twins and Triplets Series includes the plurality, birthweight, and gestational age variables and the mother's characteristics (see Table 4.13). Again, the low birthweight variable is not significant. As in the first model, there is a higher likelihood that twins will suffer the hazard of fetal death than triplets. Specifically, triplets are 40 percent less likely to experience fetal death than twins. Also, compared to optimal birthweight fetuses, very low birthweight fetuses are much more likely to suffer the hazard of fetal death. Also, over optimal birthweight fetuses are substantially more likely to experience fetal death than optimal birthweight fetuses. There is a 25.7 percent decrease in the hazard of fetal death for triplets for each week increase in gestational age, controlling for the other variables. These findings are consistent with the findings reported above in the first model.

The third model in the Twins and Triplets Series includes the variables in Model 2 and adds the sex of fetus and birth order variables (see Table 4.14). The variable which controls for plurality has a similar effect as in Models 1 and 2. Specifically, triplets are 45.5 percent less likely to suffer the hazard of fetal death than twins. Also, compared to optimal birthweight fetuses, there is a 62.5 percent decrease in the hazard of fetal death for very low birthweight fetuses. Again, the low birthweight variable is not significant. However, the over optimal birthweight variable is significant and shows that there is a huge percent increase in the hazard of fetal death for twins and triplets that are over optimal birthweight compared to those that are at optimal birthweight. Also, for each increase in the gestational age of the fetus, there is a 25.1 percent decrease in the hazard of fetal death. The significant effects of birthweight and gestational age variables on the hazard of fetal death for twins and triplets are sustained when the controls are added to the model.

As in the previous two series of models, the final model presents semi-standardized hazard coefficients which shows relative effects of all the independent variables on the hazard of twins and triplet fetal death (see Table 4.15).

Similar to the findings in the Twins-Only Series and the Triplets-Only Series, the variable with the greatest relative effect is the parity variable. The other variable with the greatest relative effect is the gestational age variable. The birthweight and plurality variables, which are also key independent variables, report large relative effects. I conclude that not only are these variables associated significantly with the hazard of a fetal death, they are among the most influential of all the independent variables in my model. Plurality, gestational age and birthweight are very important predictors of the hazard of a twin and triplet fetal death.

**Conclusion**

This chapter examined statistically the hazard of death for the twins , for triplets, and for twins and triplets combined. My goal was to see which of the predictors had an effect on the hazard of fetal death and which of the predictors seemed to be the most important. Consistently, the birthweight and gestational age variables were the most significant. In each of the three series of models, the birthweight variables and gestational age variable were shown to be very significant in predicting the hazard of fetal death for twins and triplets even after controlling for the mothers characteristics, the sex of the fetus, and the birth-order of the fetus within the multiple set. This is consistent with my hypothesis that these variables would be the most significant in predicting the hazard of fetal death. One interesting finding is that, when controlling for plurality, triplets are less likely to suffer the hazard of fetal death than twins. This makes sense once we considered the fact of increased occurrence of early emergency cesarean-section births for triplets compared to twins. Specifically, triplets are more likely to be delivered early, which makes triplets more likely to experience a live birth than twins. Another important finding in this chapter was the relative impact of parity.

The semi-standardized coefficients showed that the parity variable had the greatest relative impact in the Twins-Only and the Twins and Triplets Series and the second greatest impact in the Triplets-Only Series.  The semi-standardized coefficients for the first-born variable had the greatest impact in the Triplets-Only Series. I now turn in Chapter V to similar analyses of neonatal mortality.

# CHAPTER V

# ANALYSIS OF NEONATAL MORTALITY

This chapter of my dissertation will focus on the analysis of the hazard of neonatal death for twins and triplets born between the years 1995 and 2000. The neonatal period starts at the moment of live birth and continues through the first 27 days of life. I will describe the data, then present the results from the Cox Proportional Hazard models that will be estimated first for only twins, and then for only triplets, and finally for both twins and triplets together, with a control for plurality. Then, I will interpret the results of the models for the three series for the neonatal timing period. I now move to a description of the data.

## Descriptive Statistics

I first deleted all the fetal deaths from the dataset; this resulted in 300,380 twin and 11,238 triplet neonates. Of these, 6,717 twins and 10,659 triplets experienced neonatal death, and 293,663 twins and 10,659 triplets survived the neonatal period.

There are 6,001 twin and 562 triplet neonates who experienced neonatal death and weighed less than 1,500 grams at their live birth; this is considered to be a very low birthweight. Deaths to neonates of this very low birthweight comprise 90 percent of all neonatal deaths. This can be compared to 1,688 twin and 88 triplet neonates (or 82.5 percent of all neonatal deaths) who experienced the hazard of death during the neonatal period. Of the neonates who survived to the postneonatal period (28 days through 364 days after live birth) 9 percent of them weighed less than 1,500 grams at live birth.

There are 528 twins and 16 triplets who experienced neonatal death and weighed between 1,500-2,499 grams at live birth, which is considered to be a low birthweight. Low birthweight neonates comprise 7.5 percent of all neonatal deaths, thus indicating that twins and triplets are more likely to survive the fetal period than experience death as an infant. Of the twins and triplets who survived to the postneonatal period, 45 percent of them were considered to be of low birthweight at birth.

During the neonatal period 2.5 percent of all neonatal deaths, or 180 twins and 1 triplet experienced neonatal death and weighed between 2,500 and 3,999 grams at birth, which is considered to be optimal birthweight. However, 46 percent of the neonates who were born at this weight survived. Finally, there are 8 twins and no triplet neonates who experienced death during the neonatal period and weighed over 4,000 grams, which is a small 0.1 percent of all neonatal deaths. This same very small percentage of neonates who were born alive weighed over 4,000 grams (See Table 5.1).

The next variable I will discuss is gestational age; it ranges from 20 to 47 weeks. The mean gestational age for the sample of twins is 35 weeks (Table 5.2) and 32 weeks for triplets (Table 5.3). The mean gestational age for neonates who experienced death is 25 weeks for twins and 24 weeks for triplets. In contrast, the mean gestational age for neonates not experiencing death is 35 weeks for twins and 33 weeks for triplets (see also Tables 5.2 and 5.3).

In my models, the next variables added to the hazard regression equation pertain to the mother's characteristics. For the analyses including only twins, 68 percent of the twins have mothers who are non-Hispanic White; 14 percent of the twins have mothers who are Hispanic; and 18 percent of the twins have mothers who are non-Hispanic Black. On the other hand, 85 percent of triplets have mothers who are non-Hispanic White; 8 percent of the triplets have mothers who are Hispanic; and 8 percent of triplets have mothers who are non-Hispanic Black.

The average age for mothers of twins is 29 years (Table 5.2), and for mothers of triplets the average age is 32 (Table 5.3). On the other hand, the average age of the mother is 27 for twins (Table 5.2) and 30 for triplets (Table 5.3) for multiples who experienced neonatal death. Of the multiples who survived the hazard of neonatal death, the average age of the mother is 29 for twins (Table 5.2) and 32 for triplets (Table 5.3). This is, on average, a difference of two years for mothers who had a neonate survive versus mothers who had a neonate who died.

The final variable dealing with maternal characteristics is her parity. Of the neonates who experience the hazard of death during the neonatal period, the average parity for the mother is 2.3 for twins and 2.5 for triplets (See Figure 5.1). In contrast, the average parity is higher for the neonates who survive the hazard of death at 2.5 for mothers of twins and 2.6 for mothers of triplets.

In my third model, I will add variables that control for the sex of the neonate, and for its birth order within the multiple set. The variable controlling for the sex of the infant is a dummy, scored 1 if the neonate is a male. In this sample, 50 percent of both the twins and triplets are females. The non-Hispanic White sex ratio is 102; the non-Hispanic Black sex ratio is 100, and the Hispanic sex ratio is 98. The percentages among the twins and triplets who died show a different trend, with more male neonates dying than female neonates. Specifically, 2.4 percent of male twins died while 2.0 percent of female twins died during the neonatal period, and 5.5 percent of male and 4.7 percent of female triplets died during the neonatal period. These sex differentials in mortality are as expected.

The next variable is a dummy that specifies whether or not the neonate was the first in the multiple set to emerge from the mother; this too is a dummy, scored 1 if the neonate was the first to emerge from the mother. In this sample dataset, there are 152,678 twins and 3,723 triplets who were the first to emerge from the mother. First-born neonates compromise 50 percent of the twins and 33 percent of triplets during the neonatal period. Of the twin neonates who died, 3,620 (or 54 percent) are first-born, while 3,097 (or 46 percent) are second-born. For triplets, 202 (or 35 percent) of the triplet deaths are to the first-born, while 377 or (66 percent) of the triplet deaths occur to second- or third- born triplets. Of the twins who survived the hazard of death during the neonatal period, 148,351 (or 50.5 percent) are first-born and 145,312 or (49.5 percent) are second-born. For triplets who survived, 3,499 (or 32.8) are first-born and 7,160 (or 67.2) are second- or third-born.

**Description of the Dependent Variable**

In this section I describe the dependent variable, the hazard of the twin or triplet experiencing neonatal death; I describe the hazards graphically, using Kaplan-Meier curves (see Figures 5.1 through 5.3). The plot steps down one day at a time, starting at live birth and ending on the 28$^{th}$ day after live birth. As expected, the probability of neonatal death decreases as time moves forward.

The Kaplan-Meier Curve (see Figure 5.2) shows the survival curve for twins during the neonatal period. All twins are censored by the 28th day after live birth. The likelihood of neonatal death is at the highest level during the first 24 hours after birth. Specifically, 60.8 percent of twins who die during the neonatal period, die during the first 24 hours after birth. However, after the first day the hazard of neonatal death declines substantially with each day. These differential survival experiences are clearly shown in the K-M curve.

The next Kaplan-Meier Curve (see Figure 5.3) represents the survival plot for triplets during the neonatal period. The chart is set up the same as the Kaplan-Meier Curve for twins with the analysis beginning at live birth and all neonates being censored by the 28th day after live birth. Also, similar to twins, triplets have the highest hazard of death during the first 24 hours after birth. Specifically, 63.9 percent of triplets who died during the neonatal period experienced death during the first 24 hours of live birth.

Figure 5.4 shows the Kaplan-Meier Curves stratified for both twins and triplets during the neonatal period. The hazard of neonatal death for twins and triplets is different with twins being less likely to suffer the hazard of neonatal death than triplets who are more likely to suffer the hazard of neonatal death. I turn in the next section to the presentation of the results of the hazard regression models. I first examine the results for twins.

**Analysis of Neonatal Death for the Twins-Only Series**

The first model for the twins considers only the effects of birthweight and gestational age on the hazard of neonatal death; then I add into the model the additional independent variables of mother's characteristics; then in the final model (presented in Table 5.6), I add in the independent variables of sex of the neonate and whether it was firstborn.

I examined the independent variables for the presence of excessive multicollinearity before starting my analysis. All of the independent variables in the full model have tolerances within acceptable levels. The lowest tolerance of any of the X variables is for the parity variable with a tolerance of 0.86, and the mean tolerance of the full set of X variables is .94.

The first model in the Twins-Only Series includes the birthweight and the gestational age variables (see Table 5.4). As noted earlier, I use four birthweight dummy variables to capture birthweight; in the hazard equations, the optimal birthweight dummy is used as the reference. Compared to optimal birthweight neonates, there is a 585.1 percent increase in the hazard of neonatal death for very low birthweight twins, and a 31.1 percent increase for low birthweight neonates; and a 210.3 percent increase for neonates weighing 4,000 or more grams. This confirms the hypothesis that neonates below and above the optimal birthweight have an increased hazard of dying during the neonatal period. Also, for each additional week of gestational age, there is, on average, a 24.4 percent decrease in the hazard of neonatal death. This confirms the hypothesis that longer gestational periods tend to result in a decrease in the hazard of neonatal death.

The second model in the Twins-Only Series adds the mother's characteristics to the major independent variables (see Table 5.5). There is a huge effect in the hazard of neonatal death for very low birthweight twins and less of an effect for low birthweight twins, compared to optimal birthweight twins. The over optimal birthweight variable is no longer significant when the mother's characteristics are added into the model but the impact of gestational age remains the same.

The third model in the Twins-Only Series includes the variables in the first two models plus the sex of neonate and birth order variables (see Table 5.6). There is an enormous effect on the hazard of neonatal death for very low birthweight twins and less of an effect for the hazard of neonatal death for low birthweight neonates, compared to optimal birthweight neonates. Again, the over optimal birthweight variable is not significant. However, the gestational age variable is significant and shows that for each increase in the gestational age of the neonate, there is a decrease of 24.3 percent in the hazard of neonatal death. The significant effects of the two major independent variables on the hazard of neonatal death are sustained when the controls are added to the model.

The final model presents semi-standardized hazard coefficients which enable me to compare the relative magnitude of the partial effects of all the X variables on the hazard of neonatal death. The semi-standardized hazard coefficients allow me to ascertain which of the independent variables has the greatest relative effect on the hazard of neonatal death, and how the relative effects of my two key independent variables compare with those of all the control variables. The semi-standardized coefficients shown in Table 5.11 are based on the hazard coefficients shown in Table 5.10. They are calculated by multiplying the hazard coefficient of an X variable by its standard deviation; the metric for all the X variables has thus been changed into standard deviation units.

The variable with the greatest relative effect is the gestational age variable which shows that the higher the gestational age the neonate was when he/she experienced live birth, the less the hazard of neonatal death. The very low birthweight variable has the 2nd largest semi-standardized hazard coefficient, and the low birthweight dummy variable has the 3rd highest semi-standardized hazard coefficient. These are among the three most influential of all the independent variables in my model. Gestational age and birthweight are very important predictors of the hazard of neonatal death and are also my key independent variables. In the next section, I turn to my analyses of triplets.

**Analysis of Neonatal Death for the Triplets-Only Series**

As in the previous analysis on twins, the effects of birthweight and gestational age on the hazard of neonatal death are analyzed first. Then I add additional independent variables. The independent variables are first examined for excessive multicollinearity. All of the independent variables in the full model have acceptable tolerance levels. The lowest tolerance of any of the X variables is the gestational age variable with a tolerance of 0.75, and the mean tolerance of the full set of X variables is .87.

The first model in the Triplets-Only Series includes the birthweight variables and the gestational age variable (see Table 5.10). The very low birthweight, low birthweight and over optimal birthweight variables are not significant in this model. However, the gestational age variable is significant; its value indicates that for each additional week of gestational age there is, on average, a 333.7 percent decrease in the hazard of neonatal death. This confirms the hypothesis that longer gestational periods tend to result in a decrease in the hazard of neonatal death.

The second model in the Triplets-Only series includes the birthweight and gestational age variables, plus the variables for the mother's characteristics (see Table 5.9). Again, the very low birthweight, low birthweight, and over optimal birthweight variables are not significant. However, there is a 33.3 percent decrease in the hazard of neonatal death for triplets for each week increase in gestational age, controlling for the other variables.

The third model in the Triplets-Only Series includes the variables in Model 2 and adds the sex of neonate and birth order variables (see Table 5.10). Again, the very low birthweight, low birthweight variable, and over optimal birthweight variables are not significant. But for each increase in the gestational age of the neonate when it experienced live birth, there is a 33.1 percent decrease in the hazard of neonatal death. The significant effects of gestational age on the hazard of neonatal death for triplets are sustained when the controls are added to the model.

As in the Twins-Only Series, the final model presents semi-standardized hazard coefficients (see Table 5.11), which show the relative effects on the hazard of triplet neonatal death for all the X variables in the final model, and, specifically, how the relative effects of the birthweight and gestational age variables compare with the relative effects of the control variables.

For the Triplets-Only Series for the neonatal period, there is only one significant standardized hazard coefficient, which is for the gestational age variable. This means that the higher the gestational age the neonate was when it experienced live birth, the less the hazard of a neonatal death. In the next section, I analyze the hazard of neonatal death for twins and triplets combined, while controlling for plurality.

**Analysis of Neonatal Death for the Twins and Triplets Series**

As in the previous two Series, I begin my hazard analysis of the Twins and Triplets Series considering the effects of birthweight and gestational age on the hazard of neonatal death. However, this model is run with an addition variable, namely a dummy variable that controls for plurality. Then, I continue to add the additional variables for the mother's characteristics (see Table 5.18). Then, I estimate another model adding the independent variables of sex of the child and whether it was firstborn.

The first model in the Twins and Triplets Series includes the plurality variable, birthweight variables and the gestational age variable (see Table 5.12). All of these variables, except the over optimal birthweight are significant. The plurality variable shows that triplets are 19.9 percent less likely to suffer the hazard of neonatal death than twins. This does not confirm my hypothesis that twins are more likely to suffer the hazard of neonatal death. There is an enormous increase in the hazard of death for very low birthweight neonates and less of an increase for low birthweight neonates compared to optimal birthweight neonates. This confirms the hypothesis that neonates who were born with less that optimal birthweight will have an increased hazard of dying during the neonatal period. The over optimal birthweight variable is not significant in this model. On the other hand, for each additional week of gestational age, there is, on average, a 25 percent decrease in the hazard of neonatal death. This confirms the hypothesis that longer gestational periods result in a decrease in the hazard of neonatal death.

The second model in the Twins and Triplets Series includes the plurality, birthweight, and gestational age variables, plus the mother's characteristics (see Table 5.13). As in the first model, there is a higher likelihood that twins will suffer the hazard of neonatal death than triplets. Specifically, triplets are 18.2 percent less likely to experience neonatal death than twins. Neonates who are born below very low birthweight are much more likely to suffer the hazard of neonatal death than neonates born at an optimal birthweight. Also, low birthweight neonates are substantially more likely to experience death than optimal birthweight neonates. There is a 25.1 percent decrease in the hazard of neonatal death for triplets for each week increase in gestational age, controlling for the other variables. These findings are consistent with the findings reported above in the first model.

The third model in the Twins and Triplets Series includes the variables from the previous models but also adds the sex of neonate and birth order variables (see Table 5.14). The variable which controls for plurality has a similar effect as in Models 1 and 2. Specifically, triplets are 18.1 percent less likely to suffer the hazard of neonatal death than twins. Also, compared to optimal birthweight neonates, there is a huge increase in the hazard of neonatal death for very low birthweight neonates and less of an increase for low birthweight neonates. Again, the over optimal birthweight variable is not significant. Also, for each increase in the gestational age of the neonate, there is a 24.9 percent decrease in the hazard of neonatal death. The significant effects of birthweight and gestational age variables on the hazard of neonatal death for twins and triplets are sustained when the controls are added to the model.

The final model presents semi-standardized hazard coefficients which show relative effects of all the independent variables on the hazard of twins and triplet neonatal death (see Table 5.15).

The greatest relative effects are represented by the parity and the gestational age variables. The birthweight and plurality variables, which are also key independent variables, report significant relative effects. I conclude that not only are these variables associated significantly with the hazard of a neonatal death, they are also among the most influential of all the independent variables in my model. Plurality, gestational age and birthweight are very important predictors of the hazard of a twin and triplet neonatal death.

**Conclusion**

In this chapter I examined the hazard of neonatal death for twins, triplets, and twins and triplets combined in order to assess which predictors have the most significant effect on the hazard. As in Chapter IV, the birthweight and gestational age variables are the most significant and influential. In each of the three series of models, the birthweight variables and gestational age variable are shown to be very significant in predicting the hazard of neonatal death for twins and triplets, even after controlling for the mothers characteristics, the sex of the neonate, and the birth-order of the neonate within the multiple set. My hypothesis that gestational age and the birthweight of the infant would be the most significant predictor of neonatal death has been confirmed. Also, as in Chapter IV, I found that when controlling for plurality, triplets are less likely to suffer the hazard of death than twins. In Chapter IV I wrote that this made sense for the fetal timing period because early emergency cesarean-section births are usually more likely to occur for triplets than for twins. Specifically, triplets are more likely to be delivered early which makes triplets more likely to experience a live birth than twins. However, I hypothesized that I would see a higher level of neonatal mortality for triplet neonates than twin neonates. This hypothesis has not been confirmed in the analyses conducted in this chapter. This could be occurring because of the longer hospital stays after live birth for triplets. If this is true, I should see a higher incidence of postneonatal death for triplets than for twins, in the analyses to be presented in Chapter VI.

Another important finding in this chapter was the relative impact of gestational age and very low birthweight. The semi-standardized coefficients showed that the gestational age variable had the greatest relative impact in the Twins-Only and the Triplets-Only Series and one of the greatest impacts in the combined Twins and Triplets Series. I now turn in Chapter VI to similar analyses of postneonatal mortality.

# CHAPTER VI

## ANALYSIS OF POSTNEONATAL MORTALITY

Chapter VI of my dissertation focuses on the hazard of death during the postneonatal period for twins and triplets born between the years 1995 and 2000. The postneonatal period begins on the 28$^{th}$ day after birth and ends on the 365$^{th}$ day. This chapter will present descriptive statistics, results of the Cox Proportional Hazard models, and then an interpretation of the hazard regression results. I will now describe the dataset.

**Descriptive Statistics**

Before beginning to analyze my data, I deleted all of the cases with fetal and neonatal deaths, resulting in a dataset containing 293,663 twins and 10,659 triplets. Of the multiples who reached the postneonatal period, 1,643 twins and 73 triplets experienced death during this time period, while 292,020 twins and 10,586 triplets survived the postneonatal period.

The birthweight and gestational age variables will be the first to be described. There are 774 twins and 58 triplets who experienced a postneonatal death and had a very low weight at birth, which is less than 1,500 grams. These multiples compromise 48 percent of all postneonatal deaths. On the other hand, 97 percent of multiples survived the hazard of death during this period and weighed less than 1,500 grams at birth. Specifically, 23,678 twins and 3,186 triplets survived the hazard of postneonatal death. However, only 8.9 percent of postneonates who survived to their first birthday were born at a very low birthweight.

There are 582 twins and 13 triplets who experienced a postneonatal death and had a low weight at birth, which is a weight between 1,500 and 2,499 grams. These twins and triplets compromise 34.7 percent of all postneonatal deaths. During the postneonatal period multiples of low birthweight fared much better than multiples of a very low birthweight. Specifically, 45.3 percent of multiples who were of low birthweight survived the hazard of postneonatal death, while only 8.9 percent of multiples born of very low birthweight survived the postneonatal period.

The postneonatal population analyzed in this chapter includes twins and triplets who were of optimal weight at birth, which ranges from 2,500 to 3,999 grams. There are 283 twins and 2 triplets who experienced a postneonatal death and were of optimal weight at live birth. Multiples of optimal birthweight compromise 16.6 percent of all postneonatal deaths. Similar to the statistics for the low birthweight twins and triplets, 45.4 percent of postneonatal survivors were of optimal birthweight when born.

The final birthweight includes multiples who were over the optimal birthweight at live birth, which is 4,000 grams or more. There were only 4 twins and no triplets who were in this category (see Table 6.1).

The birthweight and the gestational age variables are my main independent variables. The gestational age variable for the cases analyzed in this chapter ranges from 20 to 47 weeks gestation. The mean gestational age for postneonatal twins (Table 6.2) is 36 weeks, and 33 for triplets (Table 6.3). The mean gestational age for postneonates who experienced death is 32 weeks for twins and 29 weeks for triplets. However, the mean gestational age for postneonates who did not experience death is 36 weeks for twins and 33 weeks for triplets (see also Tables 6.2 and 6.3).

The next variables I analyze in my models are variables accounting for the mother's characteristics. For the analysis including only twins, 68 percent of them have mothers who are non-Hispanic White; 14 percent of them have mothers who are Hispanic; and 18 percent of them have mothers who are non-Hispanic Black. On the other hand, 85 percent of triplets have mothers who are non-Hispanic White; 8 percent of the triplets have mothers who are Hispanic; and 8 percent of triplets have mothers who are non-Hispanic Black. There is a disproportionately high percentage of White mothers who have triplets. This may have occurred due to an increase in the utilization of Assisted Reproductive Technology.

The next variable dealing with the mother's characteristics is her age. The average age for mothers of twins is 29 years (Table 6.2), and 32 for mothers of triplets (Table 6.3). The average age of mothers of multiples who experienced postneonatal death is 29 for twins (Table 6.2) and 31 for triplets (Table 6.3). For the fetal and neonatal period analyses the mother's age showed that there was, on average a 2-year difference between the mother's age for the survivors compared to the mother's age for those who died, but the mother's age during the postneonatal period does not represent similar trends.

The final variable dealing with the mother's characteristics is her parity. Parity in this sample ranges from 1 to 19. The average parities for mothers of twins and mothers of triplets are 2.5 and 2.6, respectively (see Figure 6.1). Of the postneonates who experienced death, the average parity for the mother is 2.8 for twins and 2.7 for triplets. However, of the postneonates who survived the hazard of death, the average parity for the mother is 2.54 for twins and 2.60 for triplets.

The next variables I include in my models within each series include the two variables dealing with additional characteristics of the postneonate. The first indicates if the sex of the infant is male or female; half are male, half are female. However, the breakdown by race and ethnicity is a bit different. Specifically, the non-Hispanic White sex ratio is 102; the non-Hispanic Black sex ratio is 100; and the Hispanic sex ratio is 98. Broken down even further, the percentages among the twins and triplets who survived show a distinct trend with more males dying than females. Specifically, .61 percent (or 930 out of 152,674 males) of male twins died while .53 percent (or 786 out of 15,648 females) of female twins died during the postneonatal period.

The final variable specifies the birth order of the child within the multiple set. There are 148,351 twins and 3,499 triplets who are the first in the set to emerge from the mother, compromising 50 percent of the twins and 33 percent of the triplets. Of the twins who died, 49.6 percent (or 815) of them were first-born while 50.04 (or 828) were born second. Of the triplets who died, 32.9 percent (or 24) were first-born while 67.1 percent (or 49) were second- or third- born triplets. On the other hand, of the twins who survived, 50.2 percent (or 147,536) were first born and 49.5 (or 144,484) were second-born. Also, of the triplets who survived, 32.8 percent (or 3,475) are first-born and 67.17 percent (or 7,111) are second- or third- born.

**Description of the Dependent Variable**

In this section I describe the hazard of the multiple experiencing postneonatal death. This is done with Kaplan-Meier Curves, which are empirical plots representing the probability of the multiple surviving each unit in time (see Figures 6.1 through 6.3). For twins, this plot steps down one day at a time, starting at the $28^{th}$ day after live birth and censoring by the $365^{th}$ day after birth (Figure 6.2). The frequency of postneonatal death is at the highest level on the $28^{th}$ day after live birth but declines consistently until the last or $365^{th}$ day, indicating that by this time the infant survives the hazard of postneonatal death.

The next Kaplan-Meier Curve (Figure 6.3) represents the survival plot for triplets during the postneonatal period. The chart is set up the same as the previous curve for twins. Triplets have a decreasing hazard of experiencing postneonatal death as time passes. However, the chart does “jump” a bit which is due mainly to small numbers. Figure 6.4 shows the Kaplan-Meier Curve stratified for twins and triplets together during the postneonatal period. The hazards for both populations are similar.

**Analysis of Postneonatal Death for the Twins-Only Series**

The first analysis begins with the twins-only data and considers only the effects of the birthweight and gestational age variables on the hazard of death during the postneonatal period. Then, I will add the additional independent variables into more detailed models (Table 6.6).

I will first examine the independent variables for the presence of excessive multicollinearity. All of the independent variables in the full model have tolerances well within acceptable levels. The lowest tolerance of any of the X variables is the parity variable with a tolerance of 0.86, and the mean tolerance of the full set of X variables is .94.

The gestational age and birthweight variables are the first to be examined in the Twins-Only Series (see Table 6.4). As noted earlier, I use four dummy variables to capture birthweight. Compared to optimal birthweight postneonates, there is a 404.8 percent increase in the hazard of postneonatal death for very low birthweight twins; a 58.6 percent increase for low birthweight twins; and a 414.4 percent increase for twins weighing 4,000 grams or more at birth. This confirms the hypothesis that postneonates born below and above the optimal birthweight will have an increased hazard of death during the postneonatal period. Also, for each additional week of gestational age there is a 12.5 percent decrease in the hazard of postneonatal death. The hypothesis regarding longer gestational periods resulting in a decrease in the hazard of death during the postneonatal period is also confirmed.

The second model in the series of twins adds the mother's characteristics (see Table 6.5). Compared to optimal birthweight twins, there is a huge effect in the hazard of postneonatal death for very low birthweight and over optimal birthweight twins, and less of an effect for low birthweight twins. This shows a different pattern than in the neonatal timing period, analyzed in the previous chapter. Specifically, in Model 2 for the neonatal period the effect of over optimal birthweight is no longer significant, but in this model for the postneonatal period the effect is huge. The impact of gestational age remains the same.

The third model in the Twins-Only Series adds the sex and birth order variables (see Table 6.6). Compared to optimal birthweight twins, there is an enormous effect on the hazard of postneonatal death for very low birthweight and over optimal birthweight twins but lesser of an effect for the hazard of postneonatal death for low birthweight postneonates. Again, the effect of gestational age remains the same. The significant effects of my two major independent variables on the hazard of postneonatal death are sustained when the controls are added to this model.

Finally, I report the semi-standardized hazard coefficients for the full model; these show the relative magnitude on the hazard of postneonatal death of each of the X variables. These coefficients will help me to ascertain the relative effects of my two key independent variables compared with those of all the control variables. The semi-standardized coefficients shown in Table 6.11 are based on the hazard coefficients shown in Table 6.10. They are calculated by multiplying the hazard coefficient of an X variable by its standard deviation.

Of all the independent variables in my model predicting the hazard of a postneonatal death among twins, the variable with the greatest relative effect is the very low birthweight variable. Postneonates who are twins and are born at a very low birthweight experience an increased hazard of postneonatal death. This birthweight variable is one of my key independent variables. The gestational age variable has the 2$^{nd}$ largest semi-standardized hazard coefficient. I conclude that my main independent variables are significantly related to the hazard of a postneonatal death and that they are among the most influential of all the independent variables in my model. Gestational age and birthweight, particularly very low birthweight, are very important predictors of the hazard of postneonatal death. I next turn to the analyses of triplets.

**Analysis of Postneonatal Death for the Triplets-Only Series**

I now begin my hazard analysis of the triplets-only data. As in the previous series, I begin by analyzing my main independent variables, birthweight and gestational age. Then, I will move on to include the mother's characteristics. Finally, I will add in the additional variables pertaining to the sex of the infant and whether or not it was firstborn. However, before I begin my analysis, I check for excessive multicollinearity. Fortunately, all of the variables are well within the accepted tolerance levels with the lowest tolerance representing the parity variable at .802. The mean tolerance for the full set of X variables is .89.

The first model with only the birthweight and gestational age variables is presented in Table 6.10. The very low birthweight, low birthweight, and over optimal birthweight variables are not significant in this model. On the other hand, for each additional week of gestational age, there is, on average, a 13.6 percent decrease in the hazard of postneonatal death. This confirms the hypothesis that longer gestational periods result in a decrease in the hazard of postneonatal death.

The second model in the Triplets-Only series adds variables dealing with the mother's characteristics (see Table 6.9). The very low birthweight, low birthweight, and over optimal birthweight variables are still not significant. However, the gestational age variable maintains the same significance as in Model 1.

The third model in the Triplets-Only Series adds the sex and birth order variables (see Table 6.10). Again, the very low birthweight, low birthweight and over optimal birthweight variables are not significant, but the significant effects of gestational age on the hazard of postneonatal death for triplets are maintained.

As in the Twins-Only Series, the final model presents semi-standardized hazard coefficients (see Table 6.11), which show the relative effects on the hazard of triplet postneonatal death for all the X variables in the final model. I am able to use the coefficients in this table to assess the relative effects of the birthweight and gestational age variables compared with the relative effects of the control variables.

For the Triplets-Only Series for the postneonatal period, there are two significant standardized hazard coefficients, one of which is the variable measuring gestational age, one of my main independent variables. This means that the higher the gestational age of the triplet at live birth, the less the hazard of a postneonatal death. I next analyze the hazard of postneonatal death for twins and triplets combined, while controlling for plurality.

**Analysis of Postneonatal Death for the Twins and Triplets Series**

As in the previous two sets of results presented in this chapter, I begin my hazard analysis of the Twins and Triplets combined series considering the effects of birthweight and gestational age on the hazard of postneonatal death. However, unlike in the earlier analyses, in this model I add a plurality dummy variable; this allows me to control for the already demonstrated differences in postneonatal mortality for twins and triplets. Then, I add into the model the additional independent variables of mother's characteristics; and then in the final model, I add in the independent variables of sex of the child and whether it was firstborn.

The first model in the Twins and Triplets Series begins with the plurality variable, the birthweight variables and the gestational age variable (see Table 6.12). All of these variables are significant. The first variable, plurality, shows that triplets are 45.9 percent less likely to suffer the hazard of postneonatal death than twins. This does not confirm my hypothesis that twins should be more likely to suffer the hazard of postneonatal death. However, this is consistent with the findings for the fetal and neonatal periods presented in previous chapters. Compared to optimal birthweight postneonates, there is an enormous increase in the hazard of death for very low birthweight and over optimal birthweight postneonates, and less of an increase for low birthweight postneonates. This confirms the hypothesis that postneonates who were born below, or above, the optimal birthweight will have an increased hazard of dying during the postneonatal period. On the other hand, for each additional week of gestational age, there is, on average, a 12.5 percent decrease in the hazard of postneonatal death; this finding confirms the hypothesis that longer gestational periods result in a decrease in the hazard of postneonatal death.

The second model in the Twins and Triplets Series adds the mother's characteristics (see Table 6.13). As in the first model, there is a higher likelihood that twins will suffer the hazard of postneonatal death than triplets. Specifically, triplets are 30 percent less likely to experience postneonatal death than twins. Also, compared to optimal birthweight postneonates, those who are born below or above optimal birthweight are much more likely to suffer the hazard of postneonatal death. There is an 11 percent decrease in the hazard of postneonatal death for triplets for each week increase in gestational age, controlling for the other variables. These findings are consistent with the findings reported in the first model.

The third model in the Twins and Triplets combined series adds the sex of child and birth order variables (see Table 6.14). The variable which controls for plurality has a similar effect as in Models 1 and 2. Specifically, triplets are 28.6 percent less likely to suffer the hazard of postneonatal death than twins. Also, compared to optimal birthweight multiples, there is a huge increase in the hazard of postneonatal death for very low birthweight and over optimal birthweight postneonates and less of an increase for low birthweight postneonates. Also, for each increase in the gestational age of the multiple, there is a 11.4 percent decrease in the hazard of postneonatal death; this is a finding that has remained consistent throughout the first three models. The significant effects of birthweight and gestational age variables on the hazard of postneonatal death for twins and triplets are sustained when the controls are added to the model.

As in the previous two series of models, the final model presents semi-standardized hazard coefficients (see Table 6.15). The variable with the greatest relative effect is the parity variable. The other variable with the greatest relative effect is the very low birthweight variable. The other birthweight and plurality variables, which are also key independent variables, also report significant relative effects. I conclude that not only are these variables associated significantly with the hazard of a postneonatal death, but they are among the most influential of all the independent variables in my model.

Plurality, gestational age and birthweight are very important predictors of the hazard of a twin and triplet postneonatal death.

**Conclusion**

In this chapter I have analyzed the hazard of postneonatal death in three separate models. The first model includes only twins, the second only triplets, and the third twins and triplets together. The goal of the analyses is to better understand which predictors have an effect on the hazard of postneonatal death and which of them are the most significant. Consistently, the birthweight and gestational age variables were found to be the most significant. In each of the three series of models, the birthweight variables and gestational age variable are shown to be very significant predictors of the hazard of postneonatal death for both twins and triplets, even after controlling for the mothers characteristics, the sex of the multiple, and the birth-order of the multiple. This is consistent with my hypothesis that these variables would be the most significant in predicting the hazard of postneonatal death.

One very interesting finding is that triplets are less likely to suffer the hazard of postneonatal death than twins, controlling for other variables including plurality. This is consistent with the results in my previous analyses for fetal and neonatal mortality. Specifically, triplets are more likely to be delivered early and receive intensive care during their first year of life, which makes them more likely to survive the hazard of postneonatal death. Another important finding in this chapter was the relative impact of my main independent variables. Results reporting the semi-standardized coefficients showed that these variables consistently had the greatest relative impact in all my models. I now turn in Chapter VII to similar analyses as those in this and the preceding two chapters. But rather than restricting the time period, I will examine the hazard of infant death in the entire infant period, i.e., in the first year of life.

# CHAPTER VII

# ANALYSIS OF INFANT MORTALITY

Chapter VII of my dissertation is the final analysis chapter and examines the hazard of death for multiples during the entire infant period, which lasts from live birth to the first birthday. If a multiple has reached his or her first birthday then he or she has survived the hazard of infant death and is considered right censored. In this chapter I present the description of the data, show the results from the Cox Proportional Hazard models for each series of models, and then interpret the results of each of these models. I will now move on to describe the data.

## Descriptive Statistics

In order to create a dataset appropriate for this timing period, I first have to delete the fetal deaths from the dataset. However, all of the neonatal and postneonatal deaths are kept in the dataset because the neonatal and postneonatal periods make up the infant period. The dataset for the infant population contains a total of 300,390 twins and 11,238 triplets. Within this population, there are 8,360 twins and 652 triplets who experience infant death and 292,020 twins and 10,586 triplets who survive the infant period. During the fetal period, there were 302,443 twins and 11,337 triplets in total; with 2,053 twins and 99 triplet fetuses experiencing death. Of the fetuses that survived the hazard of death during the fetal period, 6,617 twins and 10,659 triplets experienced neonatal death and 1,643 twins and 73 triplets experienced postneonatal death. Of the infants who survived the fetal period, 2.2 percent of the twins and .59 percent of the triplets died during the neonatal period and 2.75 percent of twins and .65 percent of triplets died during the postneonatal period. Also, of the twins and triplets who came into this dataset at 20 weeks gestation .68 percent of twin and .09 percent of triplet fetuses; .22 percent of twin and .59 percent of triplet neonates; .55 percent of twin and .07 percent of triplet postneonates; and 2.75 percent of twin and .65 percent of triplet infants died before reaching their first birthday.

Next I will describe the birthweight variables. There are four dummy birthweight variables which have a score of 1 if the multiple was born at a weight of less than 1,500 grams for very low birthweight infants, between 1,500 and 2,499 for low birthweight infants, between 2,500 and 3,999 grams for optimal birthweight infants, and 4,000 grams plus for over optimal birthweight infants. The optimal birthweight variable is the reference. In this dataset 75 percent of the deaths occur to infants who were a very low birthweight, which includes 6,775 twins and 620 triplets. In contrast, there are 23,678 twins and 3,186 triplets who weighed less than 1,500 grams at birth and survived the hazard of infant death. Of the infants who survive this period, 8.9 percent were of very low birthweight at birth. On the other hand, 82.5 percent of all fetal deaths occurred to fetuses that weighed less than 1,500 grams at birth (not live birth) while 10.9 percent of the very low birthweight fetuses were eventually born. Also, 90 percent of all neonatal death and 48 percent of all postneonatal deaths occurred to very low birthweight infants.

Within the population of low birthweight infants, 12.6 percent experience the hazard of death during the infant period (1,110 twins and 29 triplets). On the other hand, of the twins and triplets who survive the infant period, 45.5 percent of them were considered of low birthweight. The analysis of fetal mortality showed that 12.9 percent of all fetal deaths occurred to twins and triplets who were of low birthweight. On the other hand, 7.5 percent of all neonatal deaths and 34.7 of all postneonatal deaths occurred to infants who were of low birthweight.

Interestingly, only 5.1 percent of all infant deaths occur to infants who were born at optimal birthweight (463 twins and 3 triplets). Of the infants who survive to the postneonatal period, 45.6 percent weighed an optimal birthweight at live birth. For the fetal period, 4.5 percent of fetal deaths occurred to infants of optimal birthweight while 2.5 percent of neonatal deaths and 16.6 percent of postneonatal deaths occurred to infants of optimal birthweight.

As for the over optimal birthweight population, there are 12 twins and no triplet infants who experience death during the infant period, comprising only 0.1 percent of all infant deaths. Also, 1.4 percent of infants who were born alive and survive the hazard of infant death weighed over the optimal birthweight at live birth (see Table 7.1). A miniscule number of multiples died while being over optimal birthweight.

The gestational age variable is the other key independent variable in my models. As mentioned in the literature review, birthweight and gestational age are the biggest predictors of death among infants. For this population, the mean gestational age for twins is 36 weeks (Table 7.2) and 32 for triplets (Table 7.3). The mean gestational age for infants who experience death is 27 weeks for twins and 25 weeks for triplets. In contrast, the mean gestational age for survivors is 36 weeks for twins and 33 weeks for triplets (see also Tables 7.2 and 7.3).

The mean gestational age variable for the fetal period is 35 weeks for twins and 32 weeks for twins. However, gestational age decreases drastically for fetuses that experience the hazard of death; 27 weeks for twins and 26 weeks for triplets. The mean gestational age remains the same for the fetal and neonatal periods but drops to 25 weeks for twin and 24 weeks for triplet neonates who experience the hazard of death. The mean gestational age for postneonates changes from the fetal and neonatal periods by one week to 36 weeks for twins and 33 weeks for triplets. However, the mean gestational age for postneonates who experience the hazard of death is 32 weeks for twins and 29 weeks for triplets.

The second set of models adds the characteristics of the mother as controls, specifically the race or ethnicity of the mother, her age, and her parity. For the twins-only population, 68 percent have mothers who are non-Hispanic White; 14 percent have mothers who are Hispanic; and 18 percent have mothers who are non-Hispanic Black. On the other hand, 85 percent of triplets have mothers who are non-Hispanic White; 8 percent of triplets have mothers who are Hispanic; and 8 percent of triplets have mothers who are non-Hispanic Black. The race and ethnic distribution of the population maintained itself throughout all of the time periods analyzed in this dissertation. There is a disproportionate percent of triplet mothers who are non-Hispanic White compared to twin mothers. This may be an indicator of the increased utilization of Assisted Reproductive Technologies. Unfortunately, there is no way to test such a hypothesis with the vital statistics data.

The next variable accounts for the age of the mother. The average age for mothers of twins is 29 years (Table 7.2), and 32 for triplet mothers (Table 7.3). The average age of the mother of infants who experience the hazard of infant death is 27 for twins (Table 7.2) and 30 for triplets (Table 7.3). On the other hand, the average age of the mother of infants who survive the hazard of infant death is 29 for twins (Table 7.2) and 32 for triplets (Table 7.3). This is, on average, a difference of two years for mothers who have an infant survive versus mothers who have an infant die.

For both the fetal and neonatal time periods the average age of the mother shows similar trends, 29 years for mothers of twins and 32 for triplets. However, for the average age of the mother of a fetus or neonate who experienced the hazard of death is 27 for twins and 30 for triplets, while the average age for the mother had a fetus or neonate who survived was 29 for twins and 31 for triplets. The postneonatal timing period shows a different trend with there being no significant difference between the average age of mother of surviving postneonates compared to those who experienced the hazard of postneonatal death.

The parity variable is the last variable that accounts for a characteristic of the mother. Parity, in this population runs from age 0 to 19 with the average parities for mothers of twins and mothers of triplets equaling 2.5 and 2.6, respectively (see Figure 7.1). Of the infants who experience the hazard of death during the infant period, the average parity for the mother is 2.4 for twins and 2.5 for triplets. In contrast, of the infants who survive the hazard of death, the average parity for the mother is 2.54 for twins and 2.60 for triplets.

The analysis for the fetal period showed that the average parities for mothers of twins and triplets is 2.5 and 3 respectively, however the average was 1.25 for mothers of twins and 1.36 for mothers of triplets that died. The average parity for mothers who had a multiple die during the neonatal period is 2.3 for twins and 2.5 for triplets. The parity increases slightly to 2.8 for twin mothers and 2.7 for triplet mothers who had an infant die during the postneonatal period.

The third model within each series accounts for two more important characteristics of the infant, namely the sex of the infant and his or her birth order within the set. In this population, 50 percent of both the twins and triplets are females and 50 percent are males. The non-Hispanic White sex ratio is 102; the non-Hispanic Black sex ratio is 100, and the Hispanic sex ratio is 98. The percentages among the twins and triplets who die show a different trend with more male infants experiencing the hazard of infant death than female infants. Specifically, 3 percent of male and 2.5 percent of female twins experience the hazard of infant death during the infant period and 6.2 percent of male and 5.4 percent of female triplets experience the hazard of infant death. During the fetal period, .69 percent of male twins and .66 percent of female twins died and .92 male and .83 female triplets died. During the neonatal period, 2.4 percent of male twins and 2.0 percent of female twins died while 5.5 percent of male and 4.7 percent of female triplets died. For the postneonatal period, .61 percent of male and .51 percent of female twins died while .67 percent of male triplets and .69 percent of female twins died.

The next variable indicates the birth order of the infant within the multiple set. Specifically, there are 151,971 twins and 3,701 triplets who were the first to emerge from the mother, equaling 50 percent of all twins and 33 percent of all triplets during the infant period. Within the twin population, 53 percent are first-born and 47 percent are second-born. On the other hand for the triplet population 34.6 percent are first-born and 65.3 percent are second- or third- born. Of the twins who survived the hazard of death during the infant period, 50.5 percent are first-born and 50.5 percent are second-born. For triplets who survive the hazard of infant death, 32.83 are first-born and 67.17 are second- or third- born. These trends are similar in all of the timing periods of analyzed in this dissertation.

**Description of the Dependent Variable**

This section will be utilized to describe the hazard of the multiple experiencing infant death. The first tool used to describe this hazard is the Kaplan-Meier curve which plots the timing of the event of death for the population at risk (see Figures 7.1 through 7.3). The plot steps down one day at a time, starting at live birth and ending on the 365$^{th}$ day after live birth. As expected, the probability of infant death decreases as time moves forward. The Kaplan-Meier Curve (see Figure 7.2) shows the survival curve for twins during the infant period. All twins are censored by the 365$^{th}$ day after live birth. The frequency of infant death is at the highest level on the first 24 hours after birth then decreases consistently thereafter. Specifically, 48.9 percent of twins who die during the infant period, died during the first 24 hours after birth. However, after the first day the hazard of infant death decreases substantially with each day.

The next Kaplan-Meier Curve (see Figure 7.3) represents the survival plot for triplets during the infant period. The chart is set up the same as the Kaplan-Meier Curve for twins with the analysis beginning at live birth and all infants having been censored by the 365$^{th}$ day after live birth. Also similar to twins, triplets have the highest hazard of death during the first 24 hours of life. Specifically, 56.7 percent of triplets who died during the infant period experienced death during the first 24 hours of live birth. Figure 7.4 shows the Kaplan-Meier Curve stratified for both twins and triplets during the infant period. The hazard of infant death for twins and triplets is different with twins being less likely to suffer the hazard of infant death than triplets who are more likely to die after live birth.

**Analysis of Infant Death for the Twins-Only Series**

The key independent variables, birthweight and gestational age are the first to be analyzed in this model. Then, I add in the control variables including the characteristics of the mother, then the sex and the birth order of the infant. However, before performing the analysis, I first look for excessive multicollinearity among my variables. As expected, all of the independent variables in the full model have tolerances well within acceptable levels. The lowest tolerance of any of the X variables is the parity variable with a tolerance of 0.86, and the mean tolerance of the full set of X variables is .94. I now move onto the analysis of the first model.

The birthweight and gestational age variables are the first to be analyzed in this model (see Table 7.4). There is a 407.5 percent increase in the hazard of infant death for very low birthweight twins; a 32.4 percent increase for low birthweight infants; and a

374.7 percent increase for infants weighing 4,000 or more grams compared to optimal birthweight infants. This confirms the hypothesis that infants below and above the optimal birthweight will have an increased hazard of dying during the infant period. In fact, this hypothesis is confirmed for every analysis period studied in this dissertation. The gestational age variable shows that for each additional week of gestational age there is on average, a 20.4 percent decrease in the hazard of infant death. This confirms the hypothesis that longer gestational periods tend to result in a decrease in the hazard of infant death. The gestational age variable maintains its significance throughout every analysis period studied in this dissertation and also maintains the most consistent effects of any of the independent variables on the hazard of death.

The next model controls for the characteristics of the mother (see Table7.5). The analysis shows that there is a huge effect in the hazard of infant death for very low birthweight and over optimal birthweight twins, and less of an effect for low birthweight twins compared to optimal birthweight infants. The gestational age variable remains the same when the mother's characteristics are added to the model. When this model was run for the fetal period, the effects of the low birthweight variable were no longer significant. When I analyzed the model for the neonatal period the over optimal birthweight variable was no longer significant. However, the analysis for the postneonatal period showed similar effects as the infant period analysis.

The third model for this series controls for the sex of the infant and the birth order (see Table 7.6). The analysis results in an enormous effect on the hazard of infant death for very low birthweight and over optimal birthweight twins and lesser of an effect for the hazard of infant death for low birthweight infants compared to optimal birthweight infants. Again, the gestational age variable maintains its significance. The significant effects of my two major independent variables on the hazard of infant death are sustained when the controls are added to the model. When this model was run during the other periods, the results maintained the relationship they had when the previous model was run. Specifically, for the fetal period the effects of the low birthweight variable were no longer significant; during the neonatal period, the over optimal birthweight variable was no longer significant; and the analysis of the postneonatal period showed similar effects as the infant period analysis.

The final model allows me to ascertain which of the independent variables has the greatest relative affect on the hazard of infant death through utilizing semi-standardized hazard coefficients. These coefficients also allow me to see how the relative effects of my two key independent variables compare with those of all the control variables. The semi-standardized coefficients shown in Table 7.11 are based on the hazard coefficients shown in Table 7.10. They are calculated by multiplying the hazard coefficient of an X variable by its standard deviation; the metric for all the X variables is thus in standard deviation units.

The semi-standardized hazard coefficients show that the variable with the greatest relative effect is the gestational age variable. Specifically, the higher the gestational age the infant was when he or she experienced live birth, the less the hazard of a infant death. The very low birthweight variable has the 2$^{nd}$ largest semi-standardized hazard coefficient. I conclude that not only are my key independent variables associated significantly with the hazard of an infant death, they are among the most influential of all the independent variables in my model. Gestational age and birthweight, particularly gestational age, are very important predictors of the hazard of infant death. I next turn to my analyses of triplets. Throughout all of the analyses periods examined in this dissertation, my main independent variables have been amongst the most influential of all of the independent variables in all of the models.

**Analysis of Infant Death for the Triplets-Only Series**

The analysis for the triplet infant population will begin with a model accounting for the key independent variables, birthweight and gestational age. Then, I will add in the mother's characteristics to the second model and the sex of the infant and his or her birth order for the third model. However before this analysis is run, the variables are tested for excessive multicollinearity. All of the independent variables have acceptable tolerance levels. The lowest tolerance of any of the X variables is the gestational age variable with a tolerance of 0.75, and the mean tolerance of the full set of X variables is .87.

The first model for this population includes the key independent variables (see Table 7.10). The very low birthweight, low birthweight and over optimal birthweight variables are not significant in this model. In the previous analysis, the low birthweight variable was significant for the analysis of the fetal period but was not significant in the models for the neonatal and postneonatal periods.

For each additional week of gestational age there is, on average, a 29.3 percent decrease in the hazard of infant death, which confirms the hypothesis that longer gestational periods result in a decrease in the hazard of infant death. The gestational age variable has consistently been significant for every model and within every period of analysis analyzed in this model.

The second model in the Triplets-Only Series controls for the mother's characteristics (see Table 7.9). The very low birthweight, low birthweight, and over optimal birthweight variables are still not significant but the gestational age variable maintains significance even after controlling for the mother's characteristics. This effect is consistent with the results of the analysis periods where the birthweight variables are not significant but the gestational age variable maintains significance.

The third model for this population includes controls for the sex of infant and birth order (see Table 7.10). Again, the very low birthweight, low birthweight variable and over optimal birthweight variables are not significant. However, for each increase in the gestational age, there is a 28.7 percent decrease in the hazard of infant death. The significant effects of the gestational age on the hazard of infant death for triplets are sustained when the controls are added to the model. These results are again similar to those found during the other analysis periods.

The final model presents the semi-standardized hazard coefficients (see Table 7.11) which show the relative effects of the hazard of triplet infant death on the X variables in the final model. Specifically, these coefficients show how the relative effects of the birthweight and gestational age variables compare with the relative effects of the control variables. For this series, gestational age is the only significant variable. This means that the higher the gestational age the infant was when it experienced live birth, the less the hazard of a infant death. I next analyze the hazard of infant death for twins and triplets while controlling for plurality. The gestational age variable was significant in every time period analyzed in this dissertation. These results are similar to those found in the previous analysis except that the low birthweight variable was not significant in this model when run for the fetal period and the over optimal birthweight variable was not significant when run for the neonatal timing period.

**Analysis of Infant Death for the Twins and Triplets Series**

This Series presents a hazard analysis for twins and triplets considering the effects of birthweight and gestational age but adds a control for plurality into the first model. Then, I add into the model the additional independent variables of mother's characteristics; then in the final model (which will be presented in Table 7.18), I add in the independent variables of sex of the child and whether it was firstborn.

The first model in the Twins and Triplets Series includes the plurality variable, birthweight variables and the gestational age variable (see Table 7.12). The plurality variable shows that triplets are 30.2 percent less likely to suffer the hazard of infant death than twins. This does not confirm my hypothesis that twins should be more likely to suffer the hazard of infant death. Compared to optimal birthweight infants there is an enormous increase in the hazard of death for very low birthweight infants and less of an increase for low birthweight infants. This confirms the hypothesis that infants who were born below and above the optimal birthweight will have an increased hazard of dying during the infant period. On the other hand, for each additional week of gestational age there is, on average, a 20.9 percent decrease in the hazard of infant death which confirms the hypothesis that longer gestational periods result in a decrease in the hazard of infant death. These results are similar to those found in the previous analysis except that the low birthweight variable was not significant in this model when run for the fetal period and the over optimal birthweight variable was not significant when run for the neonatal timing period.

The second model in the Twins and Triplets Series adds controls for the mother's characteristics (see Table 7.13). As in the first model, there is a higher likelihood that twins will suffer the hazard of infant death than triplets. Specifically, triplets are 22.4 percent less likely to experience infant death than twins. Also, compared to optimal birthweight infants, infants who are born at a very low, low, or over optimal birthweight are much more likely to suffer the hazard of infant death. On the other hand there is a 20.5 percent decrease in the hazard of infant death for triplets for each week increase in gestational age, controlling for the other variables. These findings are consistent with the findings reported above in the first model. These results are also similar to those found in the previous analysis except that the low birthweight variable was not significant in this model when run for the fetal period and the over optimal birthweight variable was not significant when run for the neonatal timing period.

The third model in the Twins and Triplets Series controls for the sex of infant and birth order variables (see Table 7.14). The plurality variable has a similar effect as in Models 1 and 2. Specifically, triplets are 21.7 percent less likely to suffer the hazard of infant death than twins. Also, compared to optimal birthweight infants there is a huge increase in the hazard of infant death for very low birthweight and over optimal birthweight infants and less of an increase for low birthweight infants. Also, for each increase in the gestational age of the infant, there is a 20.4 percent decrease in the hazard of infant death. The significant effects of birthweight and gestational age variables on the hazard of infant death for twins and triplets are sustained when the controls are added to the model. These results are similar to those found in the previous analysis except that the low birthweight variable was not significant in this model when run for the fetal period and the over optimal birthweight variable was not significant when run for the neonatal timing period.

As in the previous two series of models, the final model presents semi-standardized hazard coefficients which show relative effects of all the independent variables on the hazard of twins and triplet infant death (see Table 7.15). The variable with the greatest relative effects include the very low birthweight and gestational age variables. I conclude that my key independent variables are also the variables associated significantly with the hazard of an infant death. In the previous analyses chapters I also concluded this that my main independent variables are among the most significant in the models.

**Conclusion**

This chapter examined statistically the hazard of infant death for the twins, for triplets, and for twins and triplets combined. My goal was to see which of the predictors had an effect on the hazard of infant death and which of the predictors seemed to be the most important. Consistently, the birthweight and gestational age variables were the most significant. In each of the three series of models, the birthweight variables and gestational age variable were shown to be very significant in predicting the hazard of infant death for twins and triplets even after controlling for the mothers characteristics, the sex of the infant, and the birth-order of the multiple within the set. This is consistent with my hypothesis that these variables would be the most significant in predicting the hazard of infant death. An important finding in this chapter is the relative impact of my key independent variables. The semi-standardized coefficients showed that these variables had the greatest relative impact in the each series of models.

This chapter allowed me to analyze the entire infant period and look back to the fetal, neonatal, and postneonatal periods in order to inform my overall findings. I have found similar effects in all timing periods. In the next chapter I will present my conclusions.

# CHAPTER VIII

# CONCLUSIONS AND FUTURE RESEARCH

In this final chapter of my dissertation I will first focus on my main independent variables and discuss the impact of these variables on the hazard of several types of mortality. I will next summarize my findings, and then I will address my plans for future research regarding mortality among multiples. This dissertation had two main objectives: first, to examine the effects of the key independent variables on the hazards of fetal, neonatal, postneonatal, and infant death; and second, to better understand the timing of mortality among multiples during their early life. In the first section of this concluding chapter, I will now discuss and describe my key independent variables of mortality among multiples, namely birthweight and gestational age.

## Birthweight

The birthweight variables consist of four dummy variables, namely, very low birthweight (less than 1,500 grams), low birthweight (1,500 to 2,499 grams), optimal birthweight (2,500 to 3,999 grams), and over optimal birthweight (4,000 grams or more). In all my equations, the optimal birthweight variable serves as the reference. I hypothesized that a birthweight above or below the optimal birthweight range would result in an increase in the hazard of mortality. This hypothesis was supported in this dissertation. However, each analysis period of mortality showed a slightly different trend. For instance, 75 percent of the deaths examined in this dissertation occurred to infants born in the very low birthweight category. On the other hand, 82.5 percent of all fetal deaths occurred to fetuses that weighed less than 1,500 grams at birth, while 10.9

percent of the very low birthweight fetuses were eventually born. Also, 90 percent of all neonatal deaths and 48 percent of all postneonatal deaths occurred to very low birthweight infants.

Within the population of low birthweight infants, 12.6 percent experience the hazard of death during the infant period. Similarly, in my analysis of fetal mortality, 12.9 percent of all fetal deaths occurred to twins and triplets of low birthweight. On the other hand, 7.5 percent of all neonatal deaths and 34.7 of all postneonatal deaths occurred to infants of low birthweight. The trend of the survival of low birthweight infants being higher during the postneonatal period is consistent with the literature regarding multiple births. This may occur because multiples are more likely to spend part or most of the neonatal period in hospitals under intensive care.

Further evidence supporting the birthweight hypothesis is that only 5.1 percent of all infant deaths occurred to infants born at an optimal birthweight (2,500 to 3,999 grams). Unfortunately, only 45.6 percent of the multiples in this population had an optimal birthweight at their live birth. For the fetal period, 4.5 percent of fetal deaths occurred to infants of optimal birthweight, while 2.5 percent of neonatal deaths and 16.6 percent of postneonatal deaths occurred to infants of optimal birthweight. The effect of the over optimal birthweight variable is miniscule because the majority of multiples are not in this weight category. I next examine the second of my key variables, gestational age.

**Gestational Age**

The gestational age variable is one of my key independent variables. I found that the mean gestational age for twins was 36 weeks and 32 weeks for triplets. The mean gestational age for infants who experienced death was 27 weeks for twins and 25 weeks for triplets. In contrast, the mean gestational age for survivors was 36 weeks for twins and 33 weeks for triplets. The mean gestational age variable for the fetal period was 35 weeks for twins and 32 weeks for triplets. However, I found that the mean gestational age decreased drastically for fetuses that experienced the hazard of death; 27 weeks for twins and 26 weeks for triplets. The mean gestational age remained the same in analyses of the fetal and neonatal periods but dropped to 25 weeks for twin neonates and 24 weeks for triplet neonates who experienced the hazard of death. The mean gestational age for postneonates changed from the fetal and neonatal periods by one week to 36 weeks for twins and 33 weeks for triplets. However, the mean gestational age for postneonates who experienced the hazard of death was found to be 32 weeks for twins and 29 weeks for triplets.

Having discussed and described some of the main features of the key independent variables in my dissertation models of mortality among multiples, I now turn to a review and discussion of the main findings of analyses using these two principal variables as predictors of mortality.

**Main Results**

Using data from the Linked Multiple Birth File from the National Center for Health Statistics for the years 1995 to 2000, I examined in this dissertation the effect of birthweight and gestational age on mortality for twins and triplets in the United States. Several types of mortality were analyzed: fetal mortality, which occurs between 20 weeks gestation and live birth; neonatal mortality, which occurs after live birth but before the $28^{th}$ day of life; postneonatal mortality, which occurs between the $28^{th}$ day of life through the $364^{th}$ day after birth; and infant mortality, which accounts for both the neonatal and the postneonatal period together. Each timing period was examined for three separate datasets of multiples, namely, one with only twins, one with only triplets, and one with both twins and triplets together (with a control for plurality).

I estimated several series of models for each time period: the first series included only twins, the second only triplets, and the third both twins and triplets. Then, three models were estimated for each series. The first model in each series included only the main independent variables, birthweight and gestational age. Controls were then added incrementally in the second and third models. My rationale behind entering independent variables incrementally was that I wanted to be able to see the relationship of only the main independent variables on the specific timing period of mortality; and then when the controls were entered, I wanted to be able to observe if the relationship was sustained or if it disappeared. The second model included controls for the mother's race and ethnicity, her age, and her parity. In the third model I added controls for the child's characteristics, namely, the sex of child and the birth order of the multiple within the set. As I hypothesized, the two key independent variables were found to be consistently significant in the models predicting the hazard of death for the different timing periods. Also, most of the independent variables measuring the characteristics of the mother and child were significant. However, these relationships were not of direct interest because I only used those particular independent variables as controls.

I will present and discuss the semi-standardized hazard coefficients for each series (as presented in earlier chapters): the Twins-Only, Triplets-Only and Twins and Triplets series (see Tables 1-4). Semi-standardized hazard coefficients allow me to examine the relative magnitude of the partial effects on the hazard of each of the independent variables for the particular timing period being studied. With the semi-standardized hazard coefficients I am able to ascertain which of the independent variables have the greatest relative effects on the hazard of death, and how the relative effects of my key independent variables compare with those of the control variables. These semi-standardized coefficients are based on the hazard coefficients produced in the full models within each series. They are calculated by multiplying the hazard coefficient of the X variable by its standard deviation. I report the results as percent change scores in the semi-standardized hazard coefficients.

Table 1 shows the percent change values for twins-alone, triplets-alone, and twins and triplets together during the fetal period. This table shows that gestational age and very low birthweight both have a strong relative effect on the hazard of fetal death in all three series. As expected, the parity and firstborn variable also have strong relative effects. This makes sense during the fetal and neonatal periods because a fetus that is firstborn is more likely to not be born alive. This effect disappears by the postneonatal period. Table 2 shows the relative effects for the neonatal timing period. Similar to the analysis of the fetal period, birthweight and gestational age again show the

strongest relative effects for the twins-alone series. However, the relative effects of any of the birthweight variables for the triplets-only series were not found to be significant in this period. The gestational age variable shows the strongest relative effect throughout the entire dissertation. Tables 3 and 4 show the relative effects for the analyses conducted for the postneonatal and infant periods, respectively. The comparisons in these tables consistently show that the very low birthweight or the low birthweight variables and gestational age have the greatest relative effects on mortality.
There is consistently a significant increase in the hazard of infant death for very low birthweight, low birthweight, and over optimal birthweight twins compared to optimal birthweight twins in each period analyzed in this dissertation. This finding supports the hypothesis that multiples below or above the optimal birthweight will tend to have an increased hazard of dying during the each timing period.

Also, the results with respect to the gestational age variable show that for each additional week of gestational age there is a consistent and substantial decrease in the hazard of death during each timing period. This supports the hypothesis that longer gestational periods tend to result in a decrease in the hazard of mortality. The gestational age variable maintains its significance in every analysis period examined in this dissertation and also maintains the most consistent effect of all of the independent variables on the hazard of death.

The plurality variable is another important variable and is used in the third series of tests as a control in models including both twins and triplets; here my intention was to ascertain whether twins and triplets are affected by the other independent variables differently. The plurality variable consistently shows that triplets are less likely to suffer the hazard of infant death than twins. This does not support my hypothesis that twins should be more likely to suffer the hazard of infant death. However, this may be the most important finding in this dissertation. Specifically, when controlling for the other variables in this dissertation, twins are shown to be more likely to suffer the hazard of death than triplets. I turn now to some of the implications of my research and to some possible areas for future research.

**Implications and Future Research**

In my dissertation I have shown that after controlling for relevant characteristics of the mother and child, gestational age and birthweight significantly influence the hazard of mortality for twins and for triplets. This finding is consistent with the literature reviewed and discussed in Chapter II. There was one major unexpected result in my dissertation: previous literature did not indicate that there should be such a higher hazard for twins than triplets. My future research will further explore this finding.

I believe that the unexpected higher hazard of mortality for twins compared to triplets may well be due to the social and demographic characteristics of the parents of twins and triplets, particularly the possible use of Assisted Reproductive Technologies (ART). Parents of triplets tend to be older and have lower parities. The average age for mothers of twins is 29 years, and 32 for triplet mothers. Parity in this population runs from age 0 to 19, with the average parities for mothers of twins and mothers of triplets equaling 2.5 and 3 respectively. This seems to indicate that many mothers of twins have had a previous birth while many mothers of triplets have not.

Much evidence in this dissertation lends support to the idea that a comprehensive analysis needs to be undertaken that analyzes the use of Assisted Reproductive Technologies (ART), as well as the relationship that a mother's utilization of ART has on the child's hazard of mortality. Unfortunately, these data are not now accessible. Although there indeed is a question regarding the utilization of ART on the 2003 revision of the U.S. Standard Birth Certificate, the National Center for Health Statistics will not release the data because the laws have not "caught up" with the technology. My next step therefore may require my accessing data from the individual states, one by one, that use the 2003 birth certificate in order to get the information. Additionally, I would like to undertake a regional analysis of these data. I could easily control for geography with the data available, which are available at any U.S. Census Bureau Research Data Center.

**Conclusion**

Mortality among our most sensitive populations, including those under one year of age, will always be an important area of demographic and health research. Mortality among our youngest population is not only a sensitive subject but also an increasingly important indicator of the overall wellness of the population. Infant mortality in general has always been used as an indicator of population health; specifically, a high infant mortality rate indicates a population in poor health. However, if there is an increased utilization of ART procedures, the incidence of multiple births will continue to rise. Policies reducing the number of multiples within a set have been put into place, but there continues to be an increase in the number of twins and triplets in the United States.

Since multiples naturally have an increased hazard of infant mortality, compared to singletons, declines in the overall infant mortality rate may well indicate increases in the health of some populations in the United States if the data are used in the traditional ways. States such as Massachusetts, with a high incidence of the utilization of ART may show an inflated infant mortality rate, indicating poor health outcomes. In this instance, infant mortality would not be an accurate indicator of population health. Instead, a high infant mortality rate may be indicating an increased utilization of ART, which correlates with social affluence. Further analyses of the infant mortality rate taking into account the varying use in the population of ART are needed to be able to address the precise role that the infant mortality rate plays as a proxy of the general health conditions of the population.

## REFERENCES

Abraido-Lanza, A., B. Dohrenwend, D. Ng-Mak, and J. Turner. 1999. "The Latino Mortality Paradox: A Test of the "Salmon Bias" and Healthy Migran Hypotheses." *American Journal of Public Health* 89: 1543-48.

Anonymous. 1908. "The Future Value of Children." *Pediatrics* 20: 580-581.

Anonymous. 1909. "[Following Griffith JPC. The Influence of Diet on Infant Mortality.] Prevention of Infant Mortality: Being the Papers and Discussions of a Conference Held at New Haven, Connecticut, November 11, 12, 1909." *American Academy of Medicine* 51-53. Discussion.

Anonymous. 1914. "Infant Mortality – Two Resistant Groups." *Arch Pediatrics* 31: 643. Editorial

Arias, E., D. MacDorman, B. Strobino, and B. Guyer. 2003. "Annual Summary of Vital Statistics – 2002." *Paediatrics* 112 (6): 1215-1230.

Becerra, J., C.J. Hogue, H. Atrash, and N. Perez. 1991. "Infant Mortality Among Hispanics: A Portrait of Heterogeneity." *Journals of the American Medical Association* 265(2): 217-221.

Blondel B., and M. Kaminski. 2002. "Trends in the Occurrence, Determinants, and Consequences of Multiple Births." *Semin Perinatal* 26:239-249.

Bogue, D.J. 1969. *Principles of Demography*. New York, NY: John Wiley and Sons, Inc.

Boklage, C. 2005. "The Frequency and Survival Probability of Natural Twin Conceptions" in Isaac Blickstein and Louis G. Keith (eds), *Multiple Pregnancy, Second Edition,* pp. 41-50. United Kingdom: Taylor & Francis.

Bomsel-Helmreich, O., and W. Al Mufti. 2005. "The Mechanism of Monozygosity and Double Ovulation." in Isaac Blickstein and Louis G. Keith (eds), *Multiple Pregnancy, Second Edition,* pp. 25-40 . United Kingdom: Taylor & Francis.

Brosco, J. 1999. "The Early History of the Infant Mortality Rate in America: A Reflection Upon the Past and Prophecy of the Future." *Pediatrics* 103 (2): 478-485.

Buchanan, A., and K. M. Weiss. 1995. "Infant Mortality in a Mexican-American Community: Laredo, Texas, 1950-1977." *Social Biology* 38:223-241.

Caldwell, J.C. 1986. "Routes to Low Mortality in Poor Countries." *Population and Development Review* 12:171-220.

Caldwell, J.C. 2006. "Epidemics." in David Lucas (eds.), *Beginning Australian Population Studies,* pp. 2-11. Canberra, Australia: Australian National University.

Canterino, J., C. Ananth, J. Smulian, J. Harrigan, and M. Vintzileos. 2004. "Maternal Age and Risk of Fetal Death in Singleton Gestations: USA, 1995-2000. *Journal of Maternal-Fetal and Neonatal Medicine* 15 (3): 193-197.

Cervantes, A., L. Keith, and G. Wyshak. 1999. "Adverse Birth Outcomes Among Native-Born and Immigrant Women: Replicating National Evidence Regarding Mexicans at the Local Level." *Maternal and Child Health Journal* 3(2): 99-109.

Chenery, W.L. 1919. *Standards of Child Welfare: A Report of the Children's Bureau Conferences*. May and June 1919. US Children's Bureau Publication No. 60. Washington, DC: GPO General Summary.

Cho, Y., and R. Hummer. 2001. "Disability Status Differentials Across Fifteen Asian and Pacific Islander Groups and the Effect of Nativity and Duration of Residence in the U.S." *Social Biology* 48(3-4): 171-195.

Condran, G.A., and E. Crimmins-Gardner. 1978. "Public Health Measures and Mortality in U.S. Cities in the Late Nineteenth Century." *Human Ecology* 6(1):27-54.

Cone, T.E. 1979. *History of American Pediatrics*. Boston, MA: Little, Brown; 1979.

Crosby, A. W. 2003. *America's Forgotten Epidemic: The Influenza of 1918.* Second Edition. New York, NY: Cambridge University Press.

Cutler, D., and G. Miller. 2005. "The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States." *Demography* 42: 1-22.

Davis, K. 1961. *The Population of India and Pakistan*. Princeton, NJ: Princeton University Press.

Deaton, A. and C. Paxson. 2001. Mortality, Education, Income, and Inequality Among American Cohorts. Pp. 129-170 in D.A. Wise (editor) *Themes in the Economics of Aging*. Chicago: University of Chicago Press.

Dublin, L., A. Lotka, and M. Spiegleman. 1949. *Length of life*. Revised Edition. New York: Ronald Press.

Elo I.T., and S.H. Preston. 1996. "Educational Differentials in Mortality: United States, 1979-1985." *Social Science and Medicine* 42(1): 47-57.

Elo, I.T., and S.H. Preston. 1997. "Racial and Ethnic Differences in Mortality at Older Ages," in L.G. Martin and B.J. Soldo (eds.), *Racial and Ethnic Differences in the Health of Older Americans,* pp. 10-42. Washington, DC: National Academy Press.

Estee. S. 2004. "Natality" Pp. 471-405 in *The Methods and Materials of Demography,* edited by J. Siegel and D. Swanson. Elesiever Academic Press: San Diego, CA.

Ewbank, D.C., and S.H. Preston. 1990. "Personal Health Behaviour and the Decline in Infant and Child Mortality: The United States, 1900-1930." in J. Caldwell. Canberra (eds.), *What We Know About Health Transition: The Culture, Social and Behavioural Determinants of Health*, pp. 116-50: Australian National University Printing Service.

Eyler, J.M. 1979. *Victorian Social Medicine: The Ideas and Methods of William Farr*. Baltimore, MD: Johns Hopkins University Press.

Federal Interagency Forum on Child and Family Statistics. 2007. *American's Children: Key National Indicators of Well Being, 2007*. Washington, D.C.: U.S. Government Printing Office.

Fogel, R. 1994. "Economic Growth, Population Theory, and Physiology: The Bearing of Long-Term Processes of the Making of Economic Policy." *American Economic Review* 84: 369-395.

Fox, C., Kilby, M., and K. Khalid. 2005. "Contemporary Treatments for Twin-Twin Transfusion Syndrome." *Obstetrics & Gynecology*, 105 (6):1469-1477.

Friedler, S., N. Mordel, S. Lipitz, S. Mashiach, M. Glezerman, and N. Laufer 1994. "Perinatal Outcome of Triplet Pregnancies Following Assisted Reproduction." *Journal of Assisted Reproductive Genetics* 11: 459-462.

Fretts, R. "Etiology and Prevention of Stillbirth." *American Journal of Obstetrics and Gynecology* 93 (6): 1923-1935.

Frisbie, W.P., D. Forbes, and R. Rogers. 1992. "Neonatal and Postneonatal Mortality as Proxies for Cause of Death: Evidence from Ethnic and Longitudinal Comparisons." *Social Science Quarterly* 73: 535-549.

Frisbie, W.P., and S. Song. 2003. "Hispanic Pregnancy Outcomes: Differentials Over Time and Current Risk Factor Effects." *Policy Studies Journal* 32:237-52.

Frisbie,W.P. 2006. Infant Mortality Pp 251-282 in Dudley L. Poston and Michael Micklin (editors) *Handbook of Population*. Amsterdam, Netherlands: Springer Science.

Gortmaker, S., and P. Wise. 1997. "The First Injustice: Socioeconomic Disparities, Health Services Technology, and Infant Mortality." *Annual Review of Sociology* 23:147-170.

Graunt J. 1939 (reprint). *Natural and Political Observations Mentioned in a Following Index and Made on the Bills of Mortality*. London, UK: 1662. Baltimore, MD: The Johns Hopkins Press 9.

Greb, A., R. Pauli, and R. Kirby. 1987. "Accuracy of Fetal Death Reports: Comparison with Data from an Independent Stillbirth Assessment Program." *American Journal of Public Health* 77 (9): 1202-1206.

Griffith, J.P.C. 1912. The Ability of Mothers to Nurse Their Children. *Journal of the American Medical Association* 59.

Guyer, B., M. Freedman, D. Strobino, E. Sondick. 2000. "Annual Summary of Vital Statistics: Trends in the Health of Americans During the 20$^{th}$ Century." *Pediatrics* 106 (6): 1307-1317.

Hack, M., N. K. Klein, and H. G. Taylor. 1995. "Long-term Developmental Outcomes of Low Birth Weight Infants." *The Future of Children* 5: 176-196.

Haines, M.R. 2001. "The Urban Mortality Transition in the United States: 1800-1940." *Annales de Demographie Historique* 2001: 33-64.

Haines AP, D. Sanders, U. Lehmann, AK Rowe, J. Lawn, S. Jan, D. Walker, and B. Zhutta. 2007. "Achieving Child Survival Goals: Potential Contribution of Community Health Workers. *The Lancet* 369 (57): 2121-2131.

Haub, C., and M. Yanagishita. 1991. "Infant Mortality: Who's Number One?" *Population Today* 19: 6-8

Healy, B. 2006. *Beyond the Baby Count.* U.S. News and World Report (9-24), http://health.usnews.com/usnews/health/articles/060924/2healy.htm (accessed 5-1-2008)

Heffner, L. "Impact of Prenatal Care on Intrauterine Growth Restriction." in Marie McCormick and Joanna Siegal (eds.) *Prenatal Care: Effectiveness and Implementation*, pp. 175-191. Cambridge, UK: University Press.

Hoorens, S., F. Gallo, J. Cave, and J. Grant. 2007. "Can Assisted Reproductive Technologies Help to Offset Population Ageing? An Assessment of the Demographic and Economic Impact of ART in Denmark and UK: Case Report." *Human Reproduction* 1-5.

Hoover, H. 1921. *Transactions of the Eleventh Annual Meeting of the American Child Hygiene Association*. Baltimore, MD: Franklin.

Hoyert, D., T. Mathews, F. Menacker, D. Strobino, and B. Guyer. 2006. "Annual Summary of Vital Statistics – 2004." *Paediatrics*. 1172 (1): 168-183.

Hummer, R., M. Benjamins, and R. Rogers. 2004. "Race/Ethnic Disparities in Health and Mortality Among the Elderly: A Documentation and Examination of Social Factors." in N. Anderson, R. Bulatao, and B. Cohen (eds.) *Critical Perspectives on Racial and Ethnic Differences in Health in Late Life*, pp. 53-94. Washington, DC: National Research Council.

Hummer, R., M. Biegler, P. Turk, D. Forbes, W.P. Frisbie, Y. Hong, and S. Pullum. 1999. "Race/Ethnicity, Nativity, and Infant Mortality in the United States." *Social Forces* 77 (3): 1083-1118.

Hummer, R., I. Eberstein, and C. Nam. 1992. "Infant Mortality Differentials Among Hispanic Groups in Florida." *Social Forces* 70(4): 1055-1075.

Hummer, R.A., R. Rogers, C. Nam, and F. LeClere. 1999."Race/Ethnicity, Nativity, and U.S. Adult Mortality." *Social Science Quarterly* 80 (1): 136-53.

Hummer, R.., D. Powers, S. Pullium, G. Gossman, and W.P. Frisbie. 2007. "Paradox Found (Again): Infant Mortality Among the Mexican-Origin Population in the United States." *Demography* 44, 3.

Jones, K. 1983 "Sentiment and Science: The Late Nineteenth Century Pediatrician as Mother's Advisor." *Journal of Social History* 17: 79-96.

Katz, M. 1986. *In the Shadow of the Poorhouse: A Social History of Welfare in America.* New York, NY: Basic Books.

Kramer, M. (1988). Determinants of Low Birth Weight: Methodological Assessment and Meta-Analysis. *World Health Organization* 65: 663-736.

Kerr, G., J. Ying, and W. Spears. 1995. "Ethnic Differences in Causes of Infant Mortality: Texas Births, 1989 through 1991." *Texas Medicine* 91(9): 50-56.

Krieger, N., D. Rowley, A. Herman, B. Avery, and M. Phillips. 1993. "Racism, Sexism and Social Class: Implications for Studies of Health, Disease and Well-Being. *American Journal of Preventative Medicine* 9 (Supplement): 82-122.

Knox, J. 1910. "Introductory Remarks by the Chairman." Prevention of Infant Mortality: The Papers and Discussions of a conference held at New Haven, Connecticut, November 11,12, 1909." *American academy of Medicine:* 8.

Landale, N., R. Oropesa, D. Llanes, and B. Gorman. 1999. "Does Americanization Have Adverse Effects on Health?: Sress, Health Habits, and Infant Health Outcomes among Puerto Ricans." *Social Forces* 78(2): 613-641.

Landale, N., R. Oropesa, and B.K. Gorman. 2000. "Migration and Infant Death: Assimilation or Selective Migration Among Puerto Ricans." *American Sociological Review* 65:888-909.

LeClere, F., R. Rogers, and K. Peters. 1997. "Ethnicity and Mortality in the United States: Individual and Community Correlates." *Social Forces* Vol 76 (1).

Leslie, J., L. Shelley, S. Galvin, J. Diehl, A., T. Bennett, and P. Buescher. 2003. "Infant Mortality, Low Birth Weight, and Prematurely among Hispanic, White, and African American Women in North Carolina." *American Journal Of Obstetrics and Gynecology* 188(5): 1238-1240.

Liao, Y., R. Cooper, G. Cao, R. Durazo-Arvizu, J. Kaufman, A. Luke, and D. McGee. 1998. "Mortality Patterns Among Adult Hispanics: Findings From the NHIS, 1986-1990." *American Journal of Public Health* 88:227-32.

Ludmerer, K.L. 1972. "*Genetics and American society: A Historical Appraisal.*" Baltimore, MD: Johns Hopkins University Press.

Martin, J. and M. Park. 1999. "Trends in Twin and Triplet Births: 1980-1997." *National Vital Statistics Reports.* 47 (24): 1-16.

Mathews, T and M. MacDorman. 2006. "Infant Mortality Statistics from the 2004 Period Linked Birth/Infant Death Data Set." *National Vital Statistics Reports.* 255 (14): 1-32.

McCormick, M.C. 1985. "The Contribution of Low Birth Weight to Infant Mortality and Childhood Mortality." *New England Journal of Medicine* 312: 82-90.

McKeown, T. 1976. "The Modern Rise of Population." New York: Academic Press.

Meeker, E. 1972. "The Improving Health of the United States, 1850-1915." *Explorations in Economic History* 10:353-373.

Menard, S. 1995. "Applied Logistic Regression Analysis. Sage Publications." Series: *Quantitative Applications in the Social Sciences* No. 106.

National Center for Health Statistics. 2007. "Fast Stats, A to Z, Deaths/Mortality." http://www.cdc.gov/nchs/fastats/deaths.htm (accessed 4-25-2008)

Newmayer S.W. 1911. "The Warfare Against Mortality." *American Academy of Political Social Science*. 37: 532-542.

Newsholme, A. 1889. *The Elements of Vital Statistics*. 2nd ed. London, UK: Swan Sonnenshein.

O'Grada, C. 1999. "Black '47 and Beyond." *The Great Irish Famine in History, Economy and Memory*. Princeton, NJ: Princeton University Press.

O'Grada, C. 2001. "Markets and Famines: Evidence from Nineteenth Century Finland. *Economic Development and Cultural Change* 49: 575-590.

O'Grada, C. 2003. "Famine, Concepts and Causes of." in Paul Demeny and Geoffrey McNicoll (eds.), *Encyclopedia of Population*, pp. 382-385. New York, NY: Macmillan Reference USA.

Olshansky, S. J. and B. Ault. 1986. "The Fourth Stage of Epidemiologic Transition: The Age of Delayed Degenerative Diseases." *The Milbank Quarterly.* 64:355-391.

Omran, A. R., 1971. "The Epidemiologic Transition: A Theory of Epidemiology of Population Change." *Milbank Memorial Fund Quarterly* 49:509-538.

Omran, A.R. 1977. "Epidemiologic Transition in the U.S.: The Health Factor in Population Change." *Population Bulletin* 32:3-42.

Palloni, A., and J.D. Morenoff. 2001. "Interpreting the Paradoxical in the Hispanic Paradox." *Annals of the New York Academy of Sciences* 954:140-74.

Palloni, A., and E. Arias. 2004. "Paradox Lost: Explaining the Hispanic Adult Mortality Advantage." *Demography* 41(3): 385-415.

Pattnayak, S.R., and D. Shai. 1995. "Mortality Rates as Indicators of Cross-Cultural Development: Regional Variations in the Third World." *Journal of Developing Societies* XI(2): 252-262.

Pernick, M. "*The Black Stork: Eugenics and the Death of "Defective" Babies in American Medicine and Motion Pictures Since 1915*." New York, NY: Oxford University Press; 1996.

Polin, J. and W. Frangipane. 1986. Current Concepts in Management of Obstetric Problems for Pediatricians. II. Modern Concepts in the Management of Multiple Gestation. Peadiatric Clinics of North America, 33 (3): 649-61.

Poston, D. and L. Bouvier. 2010. Population and Society: An Introduction to Demography. Cambridge University Press: Cambridge, England.

Poston, D. L., M.A. Davis, and C. Lewinski. 2006. Fertility. Pp. 403-405 in Bryan Turner (editor), *The Cambridge Dictionary of Sociology*. Cambridge, England: Cambridge University Press.

Poston, D.L., and R.G. Rogers. 1985. Toward a Reformulation of the Neonatal Mortality Rate. *Social Biology* 32:1-12.

Preston, S., and M. Haines. 1991. *Fatal years: Child Mortality in Late Nineteenth-Century America*. Princeton, NJ: Princeton University Press.

Ramirez, R., and G. Patricia de la Cruz. 2003. "The Hispanic Population in the United States: March 2002." (Current Population Reports, p20-545) U.S. Census http://www.census.gov/prod/2003pubs/p20-545.pdf

Robine, J. 2003. "Epidemiological Transition." in Paul Demeny and Geoffrey McNicoll (eds.), *Encyclopedia of Population*, pp. 307-310. New York, NY: Macmillan Reference USA.

Rogers, R.G., and R. Hackenberg. 1987. "Extending Epidemiologic Transition Theory: A new Stage." *Social Biology* 34: 234-243.

Rogers, R. G., R. A. Hummer, and C.B. Nam. 2000. *Living and dying in the USA.* San Diego, CA: Academic Press.

Rumbaut, R., and J. Weeks. 1996. "Unraveling a Public Health Enigma: Why Do Immigrants Experience Superior Health Outcomes?" *Research in the Sociology of Health Care* 13B:337-391

Scheidel, W. 2003. "Ancient World, Demography of." in Paul Demeny and Geoffrey McNicoll (eds.), *Encyclopedia of Population*, pp. 44-48. New York, NY: Macmillan Reference USA.

Singh, G. K., and M. Stella, and Yu. 1996. "Adverse Pregnancy Outcomes: Differences Between US- and Foreign-Born Women in Major US Racial & Ethnic groups." *American Journal of Public Health* 86(6): 837-843.

Sorlie, P., E. Backlund, N. Johnson, and E. Rogot. 1993. "Mortality by Hispanic Status in the United States." *Journal of American Medical Association* 270(20).

Sorlie, P., E. Backlund, and J. Keller. 1995. "U.S. Mortality by Economic, Demographic, and Social Characteristics: The National Longitudinal Mortality Study." American Journal of Public Health, Vol 85:949-56.

Stockwell, E. G., J.W. Wicks, and D. J. Adamchak. 1978. "Research Needed on Socioeconomic Differentials in U.S. Mortality." *Public Health Reports* 93: 666-672.

United Nations. 2001. *Demographic Yearbook 1999*. New York: UN Publishing Division.

Van Den Oord, E.J., and D.C. Rowe. 2000. "Racial Differences in Birth Health Risk: A Quantitative Genetic Approach." *Demography* 37: 285-298.

Ventura, S., J. Martin, S. Curtin, T. Mathews, and M. Park. 2000. "Births: Final Data for 1998." *National Vital Statistics Reports* 48(3).

Williams, D. R., and C. Collins. 1995. "U.S. Socioeconomic and Racial Differences in Health: Patterns and Explanations." *Annual Review of Sociology* 21: 349-386.

Williams JW. 1915. "The Limitations and Possibilities of Prenatal Care." *Journal of the American Medical Association* 64:95–101.

Wise, P. H. 2003. "The Anatomy of a Disparity in Infant Mortality." *Annual Review Public Health* 24: 341-362.

World Bank. 1998. "*World Development Indicators."* Washington, D.C.: World Bank.

World Health Organization. 2005. *World Health Report 2005: Make Every Mother and Child Count*. Geneva, Switzerland: World Health Organization.

Wrigley, E.A. 1969. *Population and History*. New York, NY: McGraw-Hill.

Wright, V., J. Chang, G. Jeng, M. Chen, and M. Macaluso. 2006. "Assisted Reproductive Technology Surveillance-2003*." Morbidity and Mortality Weekly Report National Center for Chronic Disease Prevention and Health Promotion, CDC.*

Wright, V., J. Chang, G. Jeng, and M. Macaluso, M. 2008. "Assisted Reproductive Technology Surveillance- United States, 2003." *MMWR. National Center for Chronic Disease Prevention and Health Promotion CDC.*

# APPENDIX

## Figures

### Figure 4.1 Average Parity for the Mother of Twins or Triplets by Age of Mother

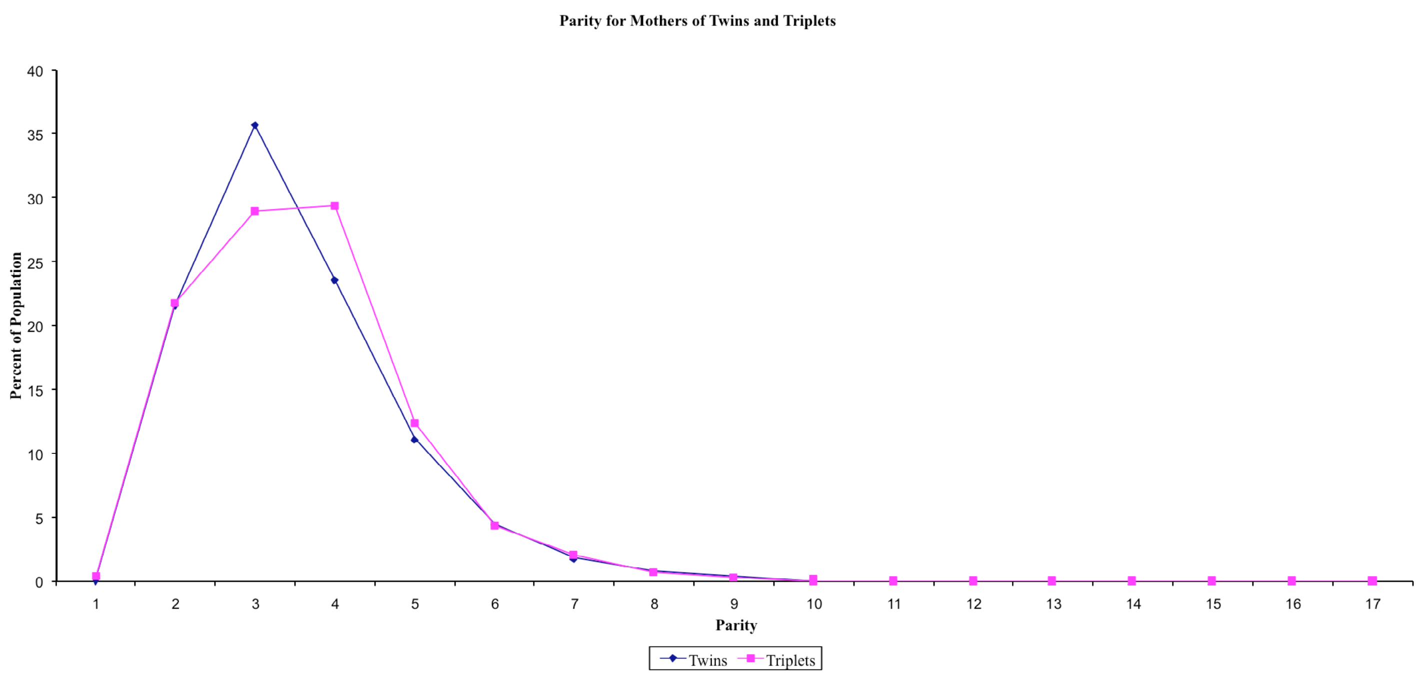


**Figure 4.2 Kaplan Meier Survival Estimate for Twins During the Fetal Period**

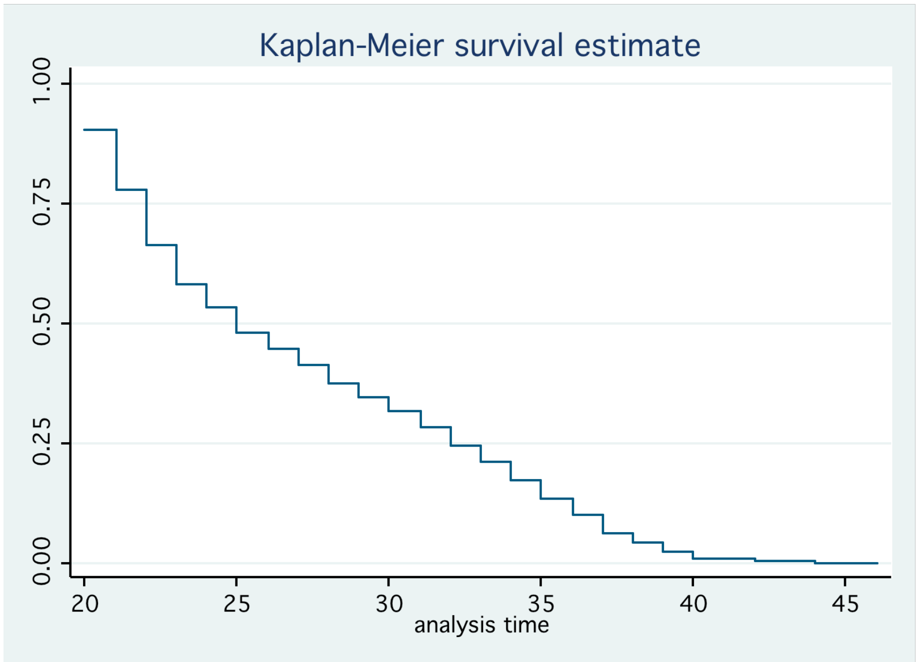


**Figure 4.3 Kaplan Meier Survival Estimate for Triplets During the Fetal Period**

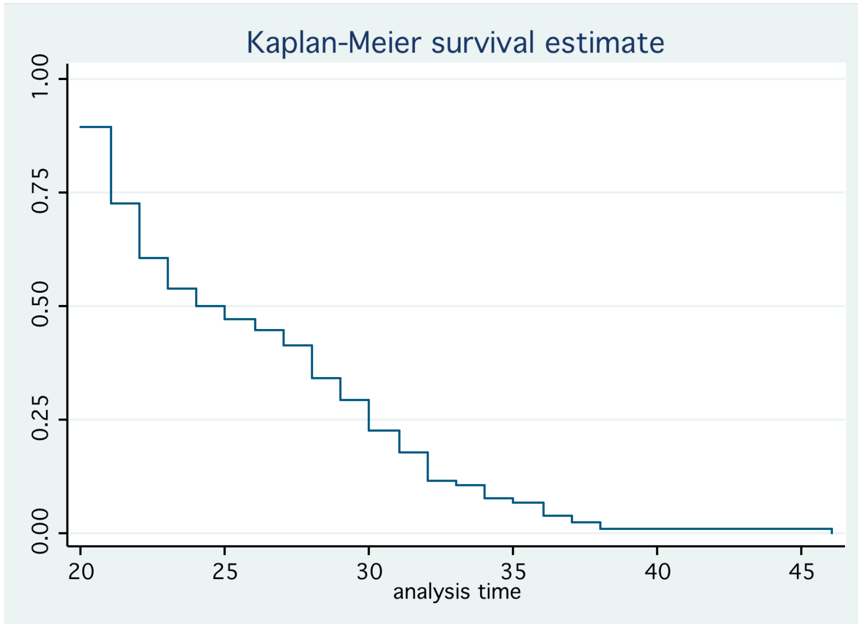


**Figure 5.1 Average Parity for the Mother of Twins or Triplets by Age of Mother**

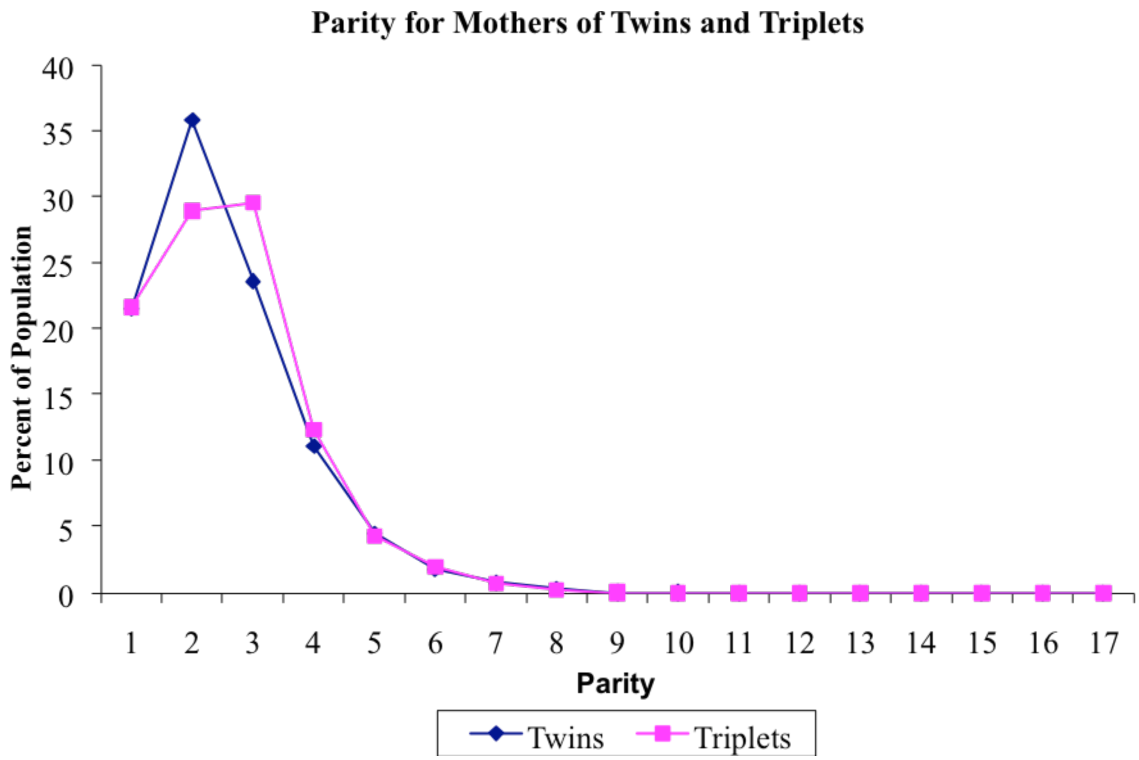


**Figure 5.2 Kaplan Meier Survival Probability Estimates for Twins During the Neonatal Period**

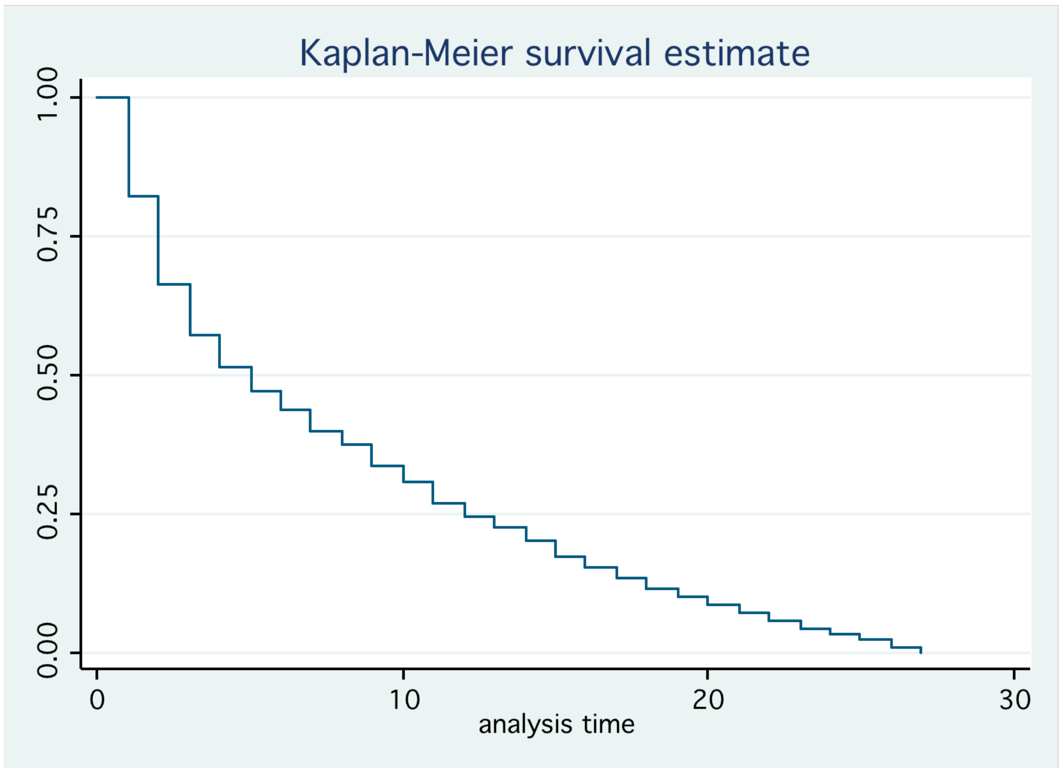


**Figure 5.3 Kaplan Meier Survival Probability Estimates for Triplets During the Neonatal Period**

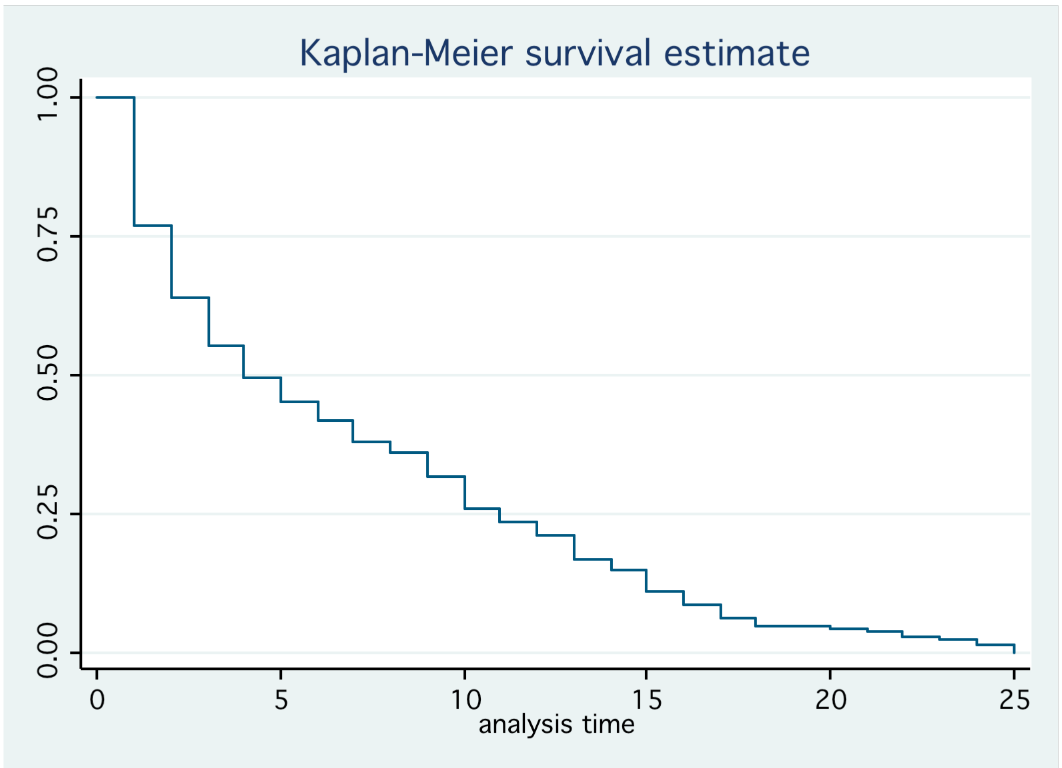


**Figure 5.4 Kaplan Meier Survival Probability Curves Stratified for Twins and Triplets**

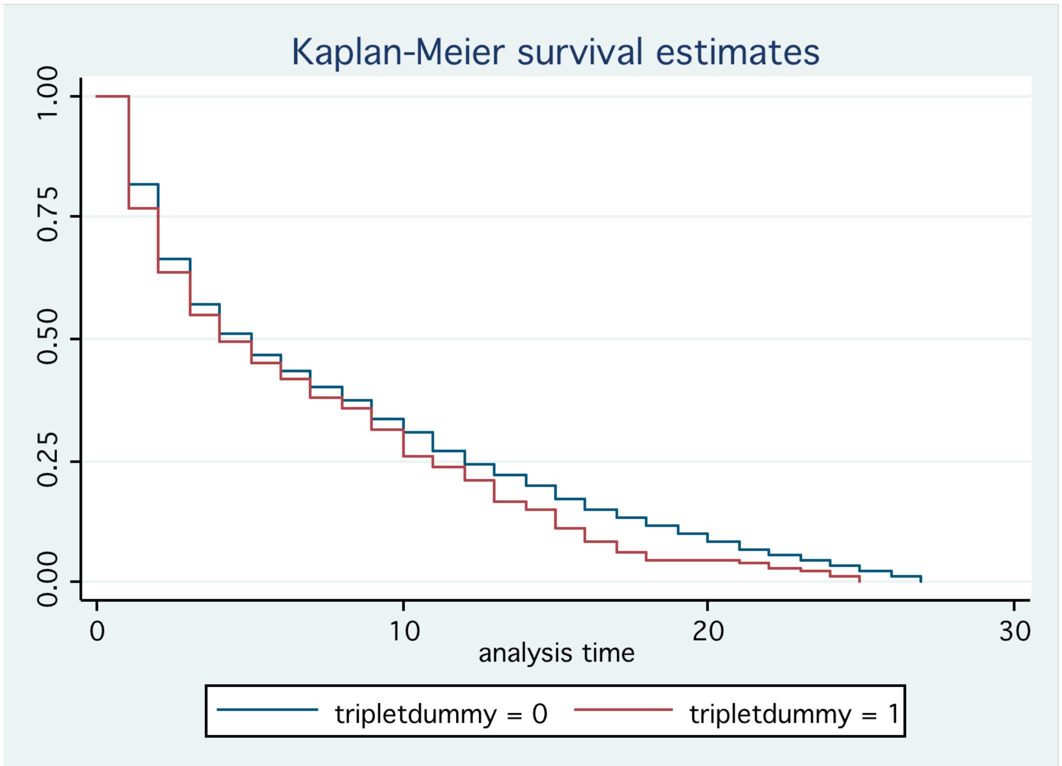


**Figure 6.1 Average Parity for the Mother of Twins or Triplets by Age of Mother**

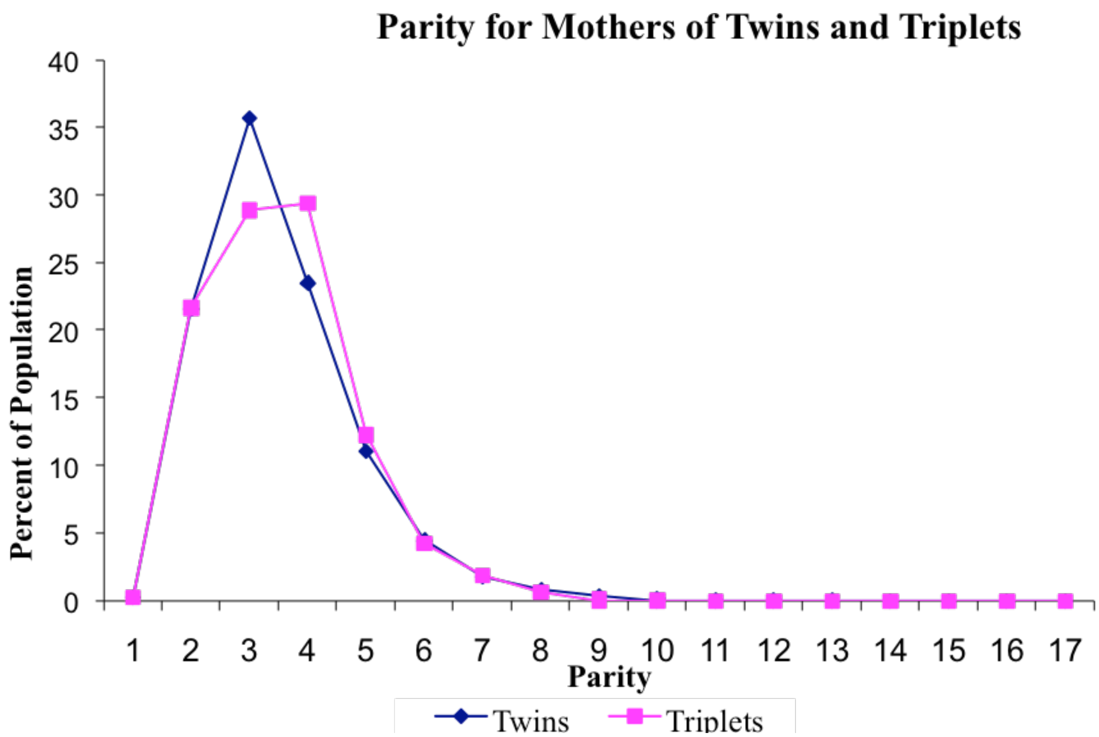


**Figure 6.2 Kaplan Meier Survival Estimate for Twins During the Postneonatal Period**

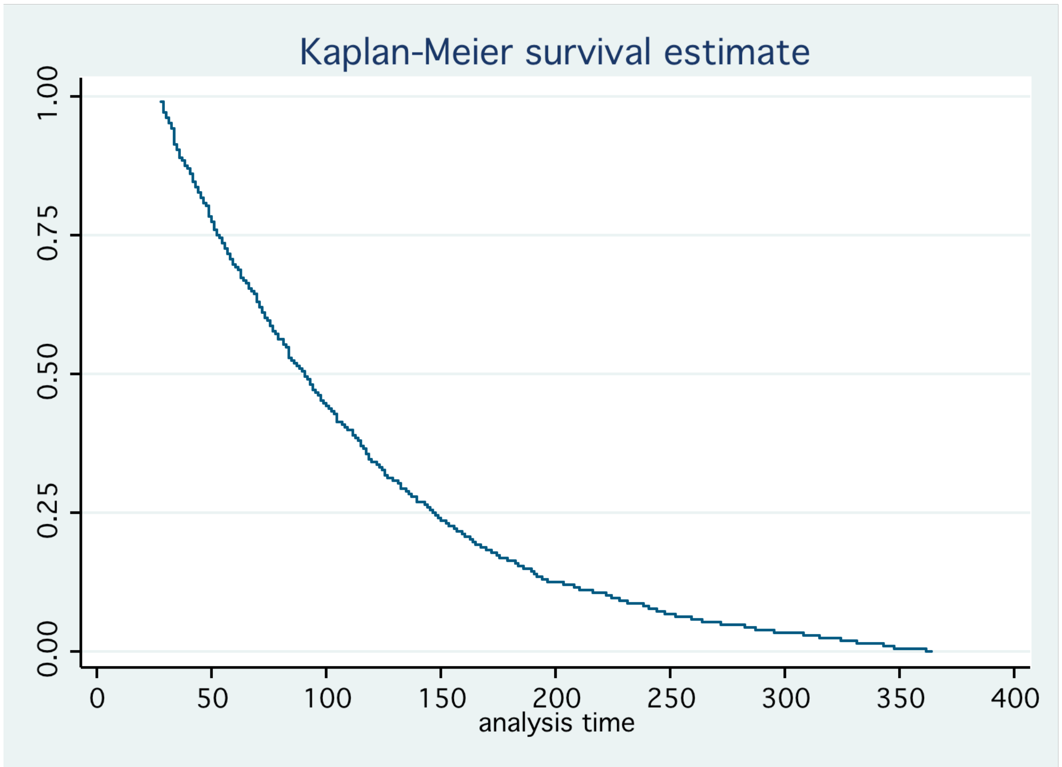


**Figure 6.3 Kaplan Meier Survival Estimate for Triplets During the Postneonatal Period**

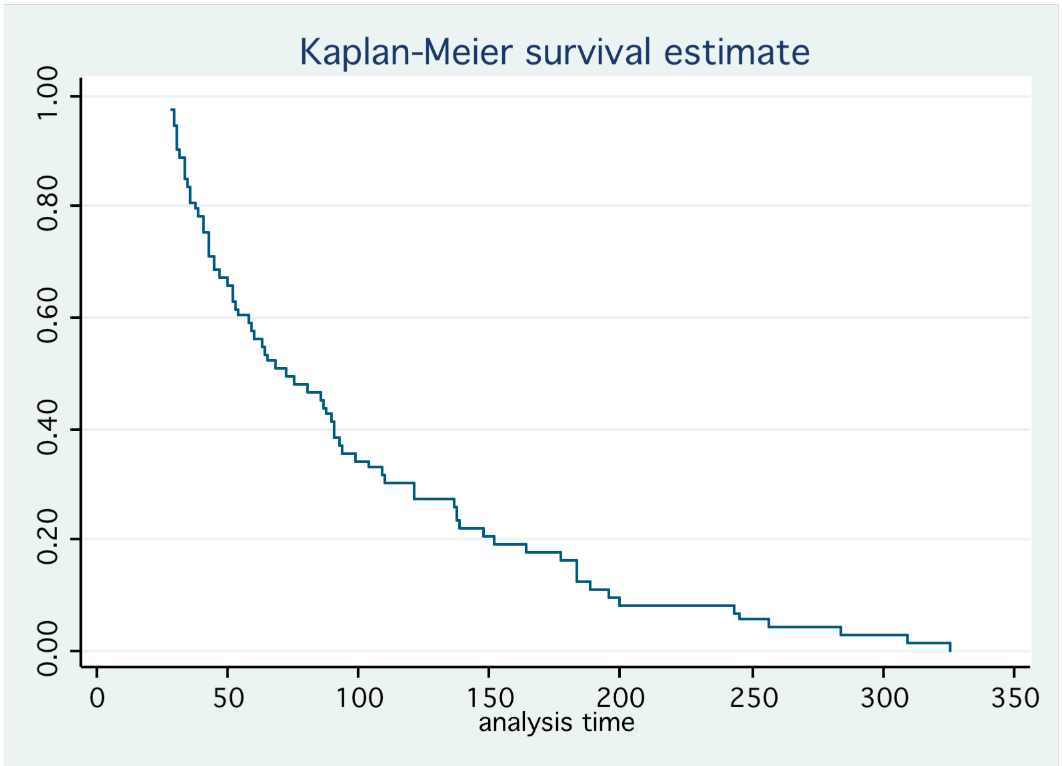


**Figure 6.4 Kaplan Meier Survival Curve Stratified for Twins and Triplets**

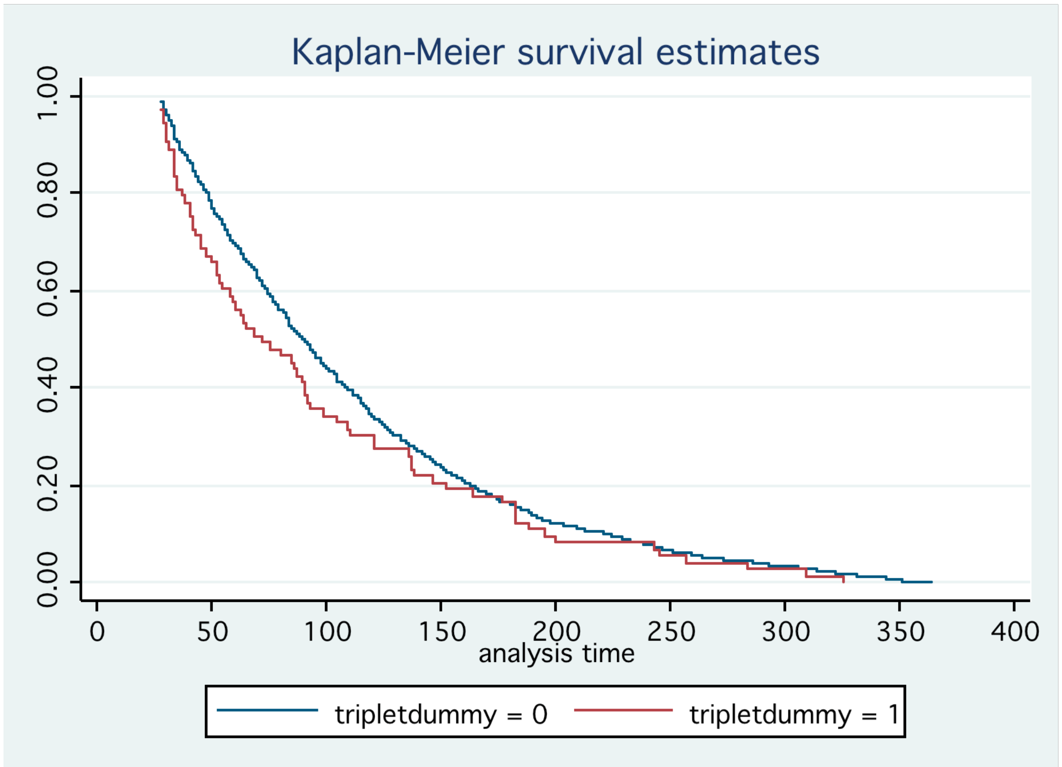


**Figure 7.1 Average Parity for the Mother of Twins or Triplets by Age of Mother**

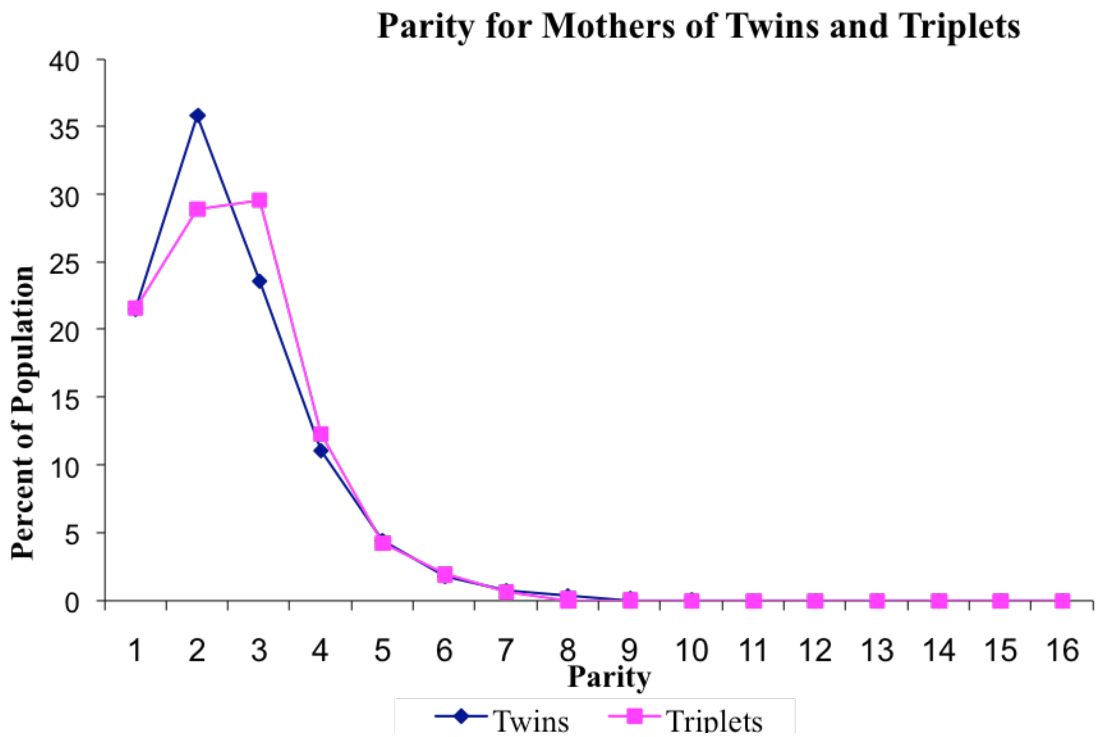


**Figure 7.2 Kaplan Meier Survival Estimate for Twins During the Infant Period**

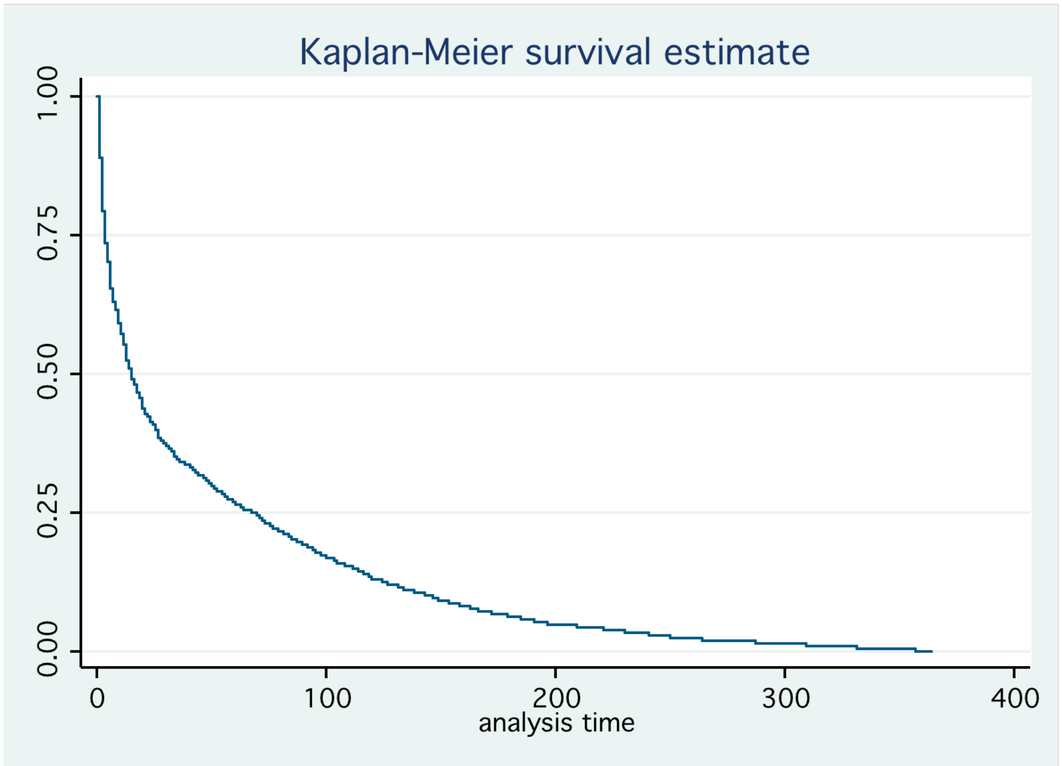


**Figure 7.3 Kaplan Meier Survival Estimate for Triplets During the Infant Period**

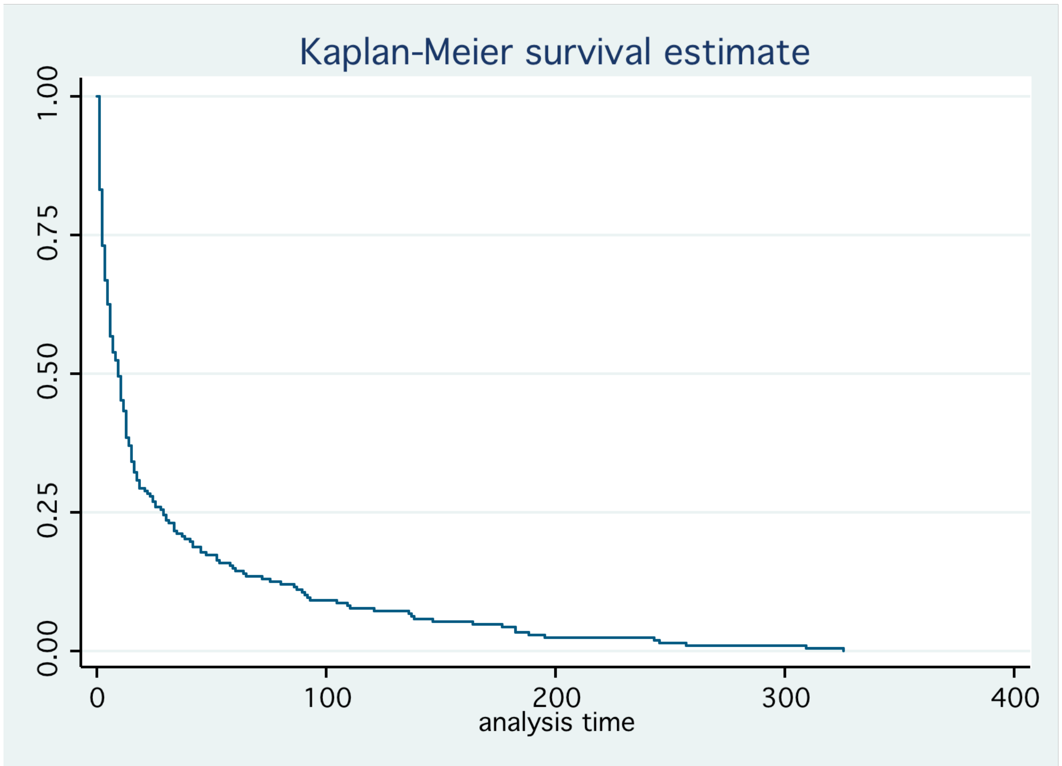
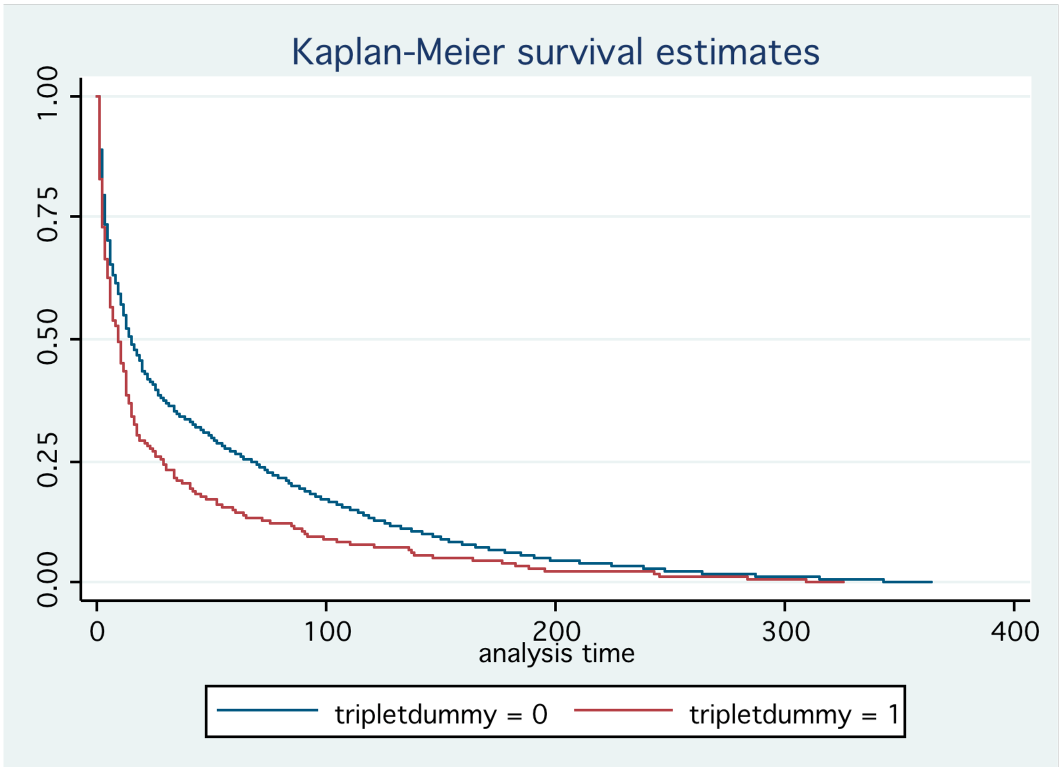


**Figure 7.4 Kaplan Meier Survival Curve Stratified for Twins and Triplets**



## Tables

### Table 1.1 Infant Mortality Rate Ranking by Country, 2008 Estimates

| Number | Country |
|---|---|
| 1 | Angola |
| 2 | Sierra Leone |
| 3 | Afghanistan |
| 4 | Liberia |
| 5 | Niger |
| 6 | Somalia |
| 7 | Mozambique |
| 8 | Mali |
| 9 | Guinea-Bissau |
| 10 | Zambia |
| 11 | Chad |
| 12 | Djibouti |
| 13 | Nigeria |
| 14 | Malawi |
| 15 | Sudan |
| 16 | Burkina Faso |
| 17 | Equatorial New Guinea |
| 18 | Rwanda |
| 19 | Congo, Democratic Republic of the |
| 20 | Ethiopia |
| 21 | Central African Republic |
| 22 | Congo, Republic of the |
| 23 | Laos |
| 24 | Lesotho |
| 25 | Western Sahara |
| 26 | Tanzania |
| 27 | Cote d'Ivoire |
| 28 | Swaziland |
| 29 | Gambia, The |
| 30 | Comoros |
| 31 | Guinea |
| 32 | Pakistan |
| 33 | Mauritania |
| 34 | Benin |

| **Number** | **Country** |
|---|---|
| 36 | Cameroon |
| 37 | Haiti |
| 38 | Nepal |
| 39 | Burundi |
| 40 | Senegal |
| 41 | Mayotte |
| 42 | Togo |
| 43 | Bangladesh |
| 44 | Cambodia |
| 45 | Azerbaijan |
| 46 | Yemen |
| 47 | Kenya |
| 48 | Madagascar |
| 49 | Gabon |
| 50 | Ghana |
| 51 | Bhutan |
| 52 | Turkmenistan |
| 53 | Vanuatu |
| 54 | Burma |
| 55 | Bolivia |
| 56 | Papua New Guinea |
| 57 | Namibia |
| 58 | Iraq |
| 59 | South Africa |
| 60 | Kiribati |
| 61 | Eritrea |
| 62 | Botswana |
| 63 | Cape Verde |
| 64 | Tajikistan |
| 65 | World |
| 66 | Timor-Leste |
| 67 | Mongolia |
| 68 | Sao Tome and Principe |
| 69 | Morocco |
| 70 | Turkey |
| 71 | Iran |
| 72 | Zimbabwe |

| Number | Country |
| --- | --- |
| 74 | Kyrgyzstan |
| 75 | Indonesia |
| 76 | Maldives |
| 77 | Guyana |
| 78 | Peru |
| 79 | Guatemala |
| 80 | Algeria |
| 81 | Egypt |
| 82 | Micronesia, Federated States of |
| 83 | Dominican Republic |
| 84 | Syria |
| 85 | Kazakhstan |
| 86 | Marshall Islands |
| 87 | Nicaragua |
| 88 | Paraguay |
| 89 | Samoa |
| 90 | Honduras |
| 91 | Uzbekistan |
| 92 | Romania |
| 93 | Bahamas, The |
| 94 | Belize |
| 95 | Vietnam |
| 96 | Trinidad and Tobago |
| 97 | Tunisia |
| 98 | Brazil |
| 99 | Lebanon |
| 100 | El Salvador |
| 101 | Venezuela |
| 102 | Libya |
| 103 | Korea, North |
| 104 | Ecuador |
| 105 | Phillippines |
| 106 | China |
| 107 | Armenia |
| 108 | Solomon Islands |
| 109 | Colombia |
| 110 | Suriname |

| **Number** | **Country** |
|---|---|
| 112 | Sri Lanka |
| 113 | Mexico |
| 114 | Gaza Strip |
| 115 | Tuvalu |
| 116 | Bulgaria |
| 117 | Saint Helena |
| 118 | Thailand |
| 119 | Antigua and Barbuda |
| 120 | Oman |
| 121 | Georgia |
| 122 | West Bank |
| 123 | Montserrat |
| 124 | Malaysia |
| 125 | Bahrain |
| 126 | Jamaica |
| 127 | Jordan |
| 128 | British Virgin Islands |
| 129 | Seychelles |
| 130 | Turks and Caicos Islands |
| 131 | Saint Kitts and Nevis |
| 132 | Aruba |
| 133 | Dominica |
| 134 | Saint Lucia |
| 135 | Palau |
| 136 | Saint Vincent and the Grenadines |
| 137 | Grenada |
| 138 | Moldova |
| 139 | Panama |
| 140 | United Arab Emirates |
| 141 | Qatar |
| 142 | Brunei |
| 143 | Mauritius |
| 145 | Fiji |
| 146 | Tonga |
| 147 | Argentina |
| 148 | Uruguay |
| 149 | Greenland |

| Number | Country |
|---|---|
| 151 | Russia |
| 152 | American Samoa |
| 153 | Nauru |
| 154 | Netherlands Antilles |
| 155 | Bosnia and Herzegovina |
| 156 | Macedonia |
| 157 | Ukraine |
| 158 | Kuwait |
| 159 | Costa Rica |
| 160 | Latvia |
| 161 | Puerto Rico |
| 162 | Hungary |
| 163 | Chile |
| 164 | Bermuda |
| 165 | Virgin Islands |
| 166 | French Polynesia |
| 167 | Estonia |
| 168 | New Caledonia |
| 169 | Cayman Islands |
| 170 | Saint Pierre and Miquelon |
| 171 | Slovakia |
| 172 | Poland |
| 173 | Cyprus |
| 174 | Northern Mariana Islands |
| 175 | Lithuania |
| 176 | Guam |
| 177 | Belarus |
| 178 | Croatia |
| 179 | Faroe Islands |
| 180 | European Union |
| 181 | United States |
| 182 | Cuba |
| 183 | Isle of Man |
| 184 | Italy |
| 185 | Taiwan |
| 186 | San Marino |
| 187 | Greece |

| Number | Country |
|---|---|
| 189 | Ireland |
| 190 | Canada |
| 191 | Jersey |
| 192 | New Zealand |
| 193 | United Kingdom |
| 194 | Gibraltar |
| 195 | Portugal |
| 196 | Australia |
| 197 | Netherland |
| 198 | Luxembourg |
| 199 | Guernsey |
| 200 | Liechtenstein |
| 201 | Belgium |
| 202 | Austria |
| 203 | Denmark |
| 204 | Slovenia |
| 205 | Korea, South |
| 206 | Israel |
| 207 | Spain |
| 208 | Switzerland |
| 209 | Germany |
| 210 | Czech Republic |
| 211 | Malta |
| 212 | Andorra |
| 213 | Norway |
| 214 | Anguilla |
| 215 | Finland |
| 216 | France |
| 217 | Iceland |
| 218 | Macau |
| 219 | Hong Kong |
| 220 | Japan |
| 221 | Sweden |
| 222 | Singapore |

**Table 1.2 Fetal, Neonatal, Postneonatal, and Infant Mortality Rates: United States 1950-2004**

| Year | Fetal | Neonatal | Postneonatal | Infant |
|---|---|---|---|---|
| 1950* | 18.4 | 20.5 | 8.7 | 29.2 |
| 1960* | 15.8 | 18.7 | 7.3 | 26 |
| 1970 | 14 | 15.1 | 4.9 | 20 |
| 1980 | 9.1 | 8.5 | 4.1 | 12.6 |
| 1985 | 7.83 | 7 | 3.7 | 10.6 |
| 1990 | 7.49 | 5.8 | 3.4 | 9.2 |
| 1995 | 6.95 | 4.9 | 2.7 | 7.6 |
| 1996 | 6.91 | 4.8 | 2.5 | 7.3 |
| 1997 | 6.78 | 4.8 | 2.5 | 7.2 |
| 1998 | 6.73 | 4.8 | 2.4 | 7.2 |
| 1999 | 6.74 | 4.7 | 2.3 | 7.1 |
| 2000 | 6.61 | 4.6 | 2.3 | 6.9 |
| 2001 | 6.51 | 4.5 | 2.3 | 6.8 |
| 2002 | 6.41 | 4.7 | 2.3 | 7 |
| 2003 | 6.23 | 4.6 | 2.2 | 6.9 |
| 2004 | 6.2 | 4.5 | 2.3 | 6.8 |

* Includes births and deaths of persons who were not residents of the 50 States and the District of Columbia
Source: Centers for Disease Control and Prevention, national Center for Health Statistics, National Vital Statistics System

**Table 1.3 Low-birthweight live births by Race and Hispanic origin: United States**

| | Year | | | | |
|---|---|---|---|---|---|
| | **1996** | **1997** | **1998** | **1999** | **2000** |
| Hispanic or Latino.................... | 6.28 | 6.42 | 6.44 | 6.38 | 6.41 |
| Mexican.............................. | 5.86 | 5.97 | 5.97 | 5.94 | 6.01 |
| Puerto Rican.......................... | 9.24 | 9.39 | 9.68 | 9.3 | 9.3 |
| Cuban................................ | 6.46 | 6.78 | 6.5 | 6.8 | 6.49 |
| Central and South American........... | 6.03 | 6.26 | 6.47 | 6.38 | 6.34 |
| Other and unknown Hispanic or Latino.. | 7.68 | 7.93 | 7.59 | 7.63 | 7.84 |
| Not Hispanic or Latino: | | | | | |
| White................................ | 6.36 | 6.47 | 6.55 | 6.64 | 6.6 |
| Black or African American............ | 13.12 | 13.11 | 13.17 | 13.23 | 13.13 |

SOURCES: Centers for Disease Control and Prevention, National Center for Health Statistics, National Vital Statistics System, Birth File.

**Table 1.4. Infant Mortality Rate by Period of Gestation**

| | Infant Mortality Rate | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **2005** | **2004** | **2003** | **2002** | **2001** | **2000** | **1999** | **1998** | **1997** | **1996** | **1995** |
| Less than 32 weeks | 183.2 | 182.5 | 188.2 | 186.4 | 181 | 780.9 | 183.3 | 184.4 | 184.6 | 188.3 | 19.4 |
| 32-33 weeks | 16.69 | 16.06 | 16.42 | 17.63 | 17.62 | 17.37 | 17.52 | 17.75 | 18.14 | 19.53 | 20.61 |
| 34-36 weeks | 7.3 | 7.32 | 7.12 | 7.66 | 7.32 | 7.96 | 7.64 | 8.16 | 8.38 | 8.87 | 9.31 |
| 37-41 weeks | 2.43 | 2.39 | 2.42 | 2.48 | 2.54 | 2.59 | 2.67 | 2.76 | 2.79 | 2.91 | 3.06 |
| -37-39 weeks | 2.63 | 2.61 | 2.6 | 2.69 | 2.75 | 2.87 | 2.92 | 3.03 | 3.06 | 3.24 | 3.42 |
| -40-41 weeks | 2.02 | 2 | 2.1 | 2.11 | 2.19 | 2.16 | 2.31 | 2.36 | 2.44 | 2.5 | 2.6 |
| 42 weeks or more | 2.66 | 2.87 | 2.88 | 3.07 | 2.95 | 2.91 | 2.9 | 3.25 | 3.46 | 3.43 | 3.48 |

Sources: Centers for Disease Control and Prevention, National Center for Health Statistics,

National Vital Statistics System, Birth File.

**Table 2.1 Infant Mortality Rates by Race and Ethnicity: United States, 2005**

| Rates are infant deaths per 1,000 live births | |
|---|---|
| **Race and Ethnicity** | **Rate** |
| Puerto Rican | 8.3 |
| Cuban | 4.42 |
| Central and South American | 4.68 |
| Asian or Pacific Islander | 4.89 |
| Mexican | 5.53 |
| American Indian or Alaskan Native | 8.06 |
| Non-Hispanic White | 8.76 |
| Non-Hispanic Black | 13.63 |

Source: NCHS 2008

**Table 3.1 Outline of Dissertation**

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| **Twins-Only** | Very Low-/ Low- / Over- Optimal Birthweight; Gestational Age | Hispanic Ethnicity of Mother/non-Hispanic Black Race of Mother; Age of Mother; Parity of Mother | Sex of child; Birth Order of child | All variables from Models 1-3 | Standardized on Model 4 |
| **Triplets-Only** | Very Low-/ Low- / Over- Optimal Birthweight; Gestational Age | Hispanic Ethnicity of Mother/non-Hispanic Black Race of Mother; Age of Mother; Parity of Mother | Sex of child; Birth Order of child | All variables from Models 1-3 | Standardized on Model 4 |
| **Twins & Triplets** | Plurality; Very Low-/ Low- / Over- Optimal Birthweight; Gestational Age | Plurality; Hispanic Ethnicity of Mother/non-Hispanic Black Race of Mother; Age of Mother; Parity of Mother | Plurality; Sex of child; Birth Order of child | All variables from Models 1-3 | Standardized on Model 4 |
| **Twins-Only** | Very Low-/ Low- / Over- Optimal Birthweight; Gestational Age | Hispanic Ethnicity of Mother/non-Hispanic Black Race of Mother; Age of Mother; Parity of Mother | Sex of child; Birth Order of child | All variables from Models 1-3 | Standardized on Model 4 |

**Table 3.2 Percent Change of the Hazard of Fetal Death for the Inclusive Model: Comparison of the Sample Dataset and Full Dataset**

| | Twins-Only Series | | | Triplets-Only Series | | | Twins and Triplets-Series | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Sample Dataset Percent Change | Full Dataset Percent Change | Absolute Difference | Sample Dataset Percent Change | Full Dataset Percent Change | Absolute Difference | Sample Dataset Percent Change | Full Dataset Percent Change | Absolute Difference |
| Plurality | ** | ** | ** | ** | ** | ** | -45.5 | -45.9 | 0.4 |
| Very Low Birthweight | 301 | 327.2 | 26.2 | *** | *** | *** | -62.5 | 349.7 | 412.2 |
| Low Birthweight | *** | 36 | 36 | -85.8 | -75.9 | 9.9 | *** | 30.3 | 30.3 |
| Over Birthweight | 1486.8 | 937.6 | 549.2 | ** | 989.5 | 989.5 | 1447.7 | 1114.3 | 333.4 |
| Gestational Age | -24.8 | -23.7 | 1.1 | -29.7 | -26.1 | 3.6 | -25.1 | -23.9 | 1.2 |
| Hispanic | -29.5 | -30.8 | 1.3 | *** | *** | *** | -29.6 | -29.9 | 0.3 |
| Non-Hispanic Black | 12.8 | 19.2 | 6.4 | 103.5 | 111.7 | 8.2 | 14.2 | 17 | 2.8 |
| Age of Mother | 0.8 | 0.7 | 0.1 | *** | *** | *** | 0.8 | 0.6 | 0.2 |
| Parity | -74.5 | -75.7 | 1.2 | -77.6 | -75.5 | 2.1 | -74.7 | -75.6 | 0.9 |
| Male | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| Firstborn | -75.1 | -76.4 | 1.3 | -82.3 | -84.5 | 2.2 | -75.4 | -76.9 | 1.5 |

** no observations

*** not significant

**Table 3.3 Percent Change of the Hazard of Neonatal Death for the Inclusive Model: Comparison of the Sample Dataset and Full Dataset**

| | Twins-Only | | | Triplets-Only Series, | | | Twins and Triplets-Series | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Sample Dataset Percent Change | Full Dataset Percent Change | Absolute Difference | Sample Dataset Percent Change | Full Dataset Percent Change | Absolute Difference | Sample Dataset Percent Change | Full Dataset Percent Change | Absolute Difference |
| **Plurality** | ** | ** | ** | ** | ** | ** | -18.1 | -18.7 | 0.6 |
| **Very Low Birthweight** | 603.4 | 626.3 | 22.9 | *** | *** | *** | 546 | 543.9 | 2.1 |
| **Low Birthweight** | 33.7 | 33.6 | 0.1 | *** | *** | *** | 28.2 | 26.4 | 1.8 |
| **Over Birthweight** | *** | *** | *** | ** | ** | ** | *** | *** | *** |
| **Gestational Age** | -24.3 | -24.3 | 0 | -33.1 | -33.7 | 0.6 | -24.9 | -25.3 | 0.4 |
| **Hispanic** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| **Non-Hispanic Black** | -20.8 | -18.9 | 1.9 | *** | *** | *** | -19.5 | -18 | 1.5 |
| **Age of Mother** | -1.8 | -1.7 | 0.1 | *** | -2 | 2 | -1.9 | -1.7 | 0.2 |
| **Parity** | 3.6 | 4 | 0.4 | *** | *** | *** | 3.8 | 4.2 | 0.4 |
| **Male** | 26.8 | 26.2 | 0.6 | *** | 22.7 | 22.7 | 26.5 | 26.4 | 0.1 |
| **Firstborn** | *** | *** | *** | *** | *** | *** | *** | *** | *** |

** no observations

*** not significant

**Table 3.4 Percent Change of the Hazard of Postneonatal Death for the Inclusive Model: Comparison of the Sample Dataset and Full Dataset**

| | Twins-Only | | | Triplets-Only Series | | | Twins and Triplets-Series | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Sample Dataset Percent Change | Full Dataset Percent Change | Absolute Difference | Sample Dataset Percent Change | Full Dataset Percent Change | Absolute Difference | Sample Dataset Percent Change | Full Dataset Percent Change | Absolute Difference |
| Plurality | ** | ** | ** | ** | ** | ** | -28.6 | -25.2 | 3.4 |
| Very Low Birthweight | 390.8 | 437.4 | 46.6 | *** | 339.9 | 339.9 | 391.7 | 420.7 | 29 |
| Low Birthweight | 54.6 | 61.6 | 7 | *** | *** | *** | 52.3 | -84.3 | 136.6 |
| Over Birthweight | 388.2 | 366 | 22.2 | ** | ** | ** | 387.2 | 367.9 | 19.3 |
| Gestational Age | -11.5 | -10.9 | 0.6 | -13.1 | -20.1 | 7 | -11.4 | -11.3 | 0.1 |
| Hispanic | -11.4 | *** | *** | *** | *** | *** | *** | *** | *** |
| Non-Hispanic Black | 38.3 | 44.4 | 6.1 | 164.3 | 129.4 | 34.9 | 41.4 | 47.6 | 6.2 |
| Age of Mother | -5.8 | -5.8 | 0 | *** | -2.7 | 2.7 | -5.6 | -5.7 | 0.1 |
| Parity | 19.6 | 19.9 | 0.3 | *** | 15.6 | 15.6 | 19 | 19.5 | 0.5 |
| Male | 21.7 | 22.5 | 0.8 | *** | *** | *** | 20.9 | 22.5 | 1.6 |
| Firstborn | *** | *** | *** | *** | *** | *** | *** | *** | *** |

** no observations

*** not significant

**Table 3.5 Percent Change of the Hazard of Infant Death for the Inclusive Model: Comparison of the Sample Dataset and Full Dataset**

| | Twins-Only | | | Triplets-Only Series | | | Twins and Triplets-Series | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Sample Dataset Percent Change | Full Dataset Percent Change | Absolute Difference | Sample Dataset Percent Change | Full Dataset Percent Change | Absolute Difference | Sample Dataset Percent Change | Full Dataset Percent Change | Absolute Difference |
| Plurality | ** | ** | ** | ** | ** | ** | -21.7 | -21.1 | 0.6 |
| Very Low Birthweight | 421.5 | 437.4 | 15.9 | *** | 340.5 | *** | 391.4 | 402.7 | 11.3 |
| Low Birthweight | 33.5 | 61.6 | 28.1 | *** | *** | *** | 28.7 | 29.9 | 1.2 |
| Over Birthweight | 354.7 | 366 | 11.3 | ** | ** | ** | 356.3 | 351.1 | 5.2 |
| Gestational Age | -19.9 | -10.9 | 9 | -28.7 | -30.4 | 1.7 | -20.4 | -20.6 | 0.2 |
| | | | | | | | | | |
| Hispanic | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| Non-Hispanic Black | *** | 44.4 | 44.4 | 58.1 | 38.1 | 20 | *** | *** | *** |
| Age of Mother | -3.3 | -5.8 | 2.5 | *** | -2.2 | 2.2 | -3.2 | -3.2 | 0 |
| Parity | 9.7 | 19.9 | 10.2 | *** | 9.1 | 9.1 | 9.5 | 9.9 | 0.4 |
| | | | | | | | | | |
| Male | 24.9 | 22.5 | 2.4 | *** | 23.1 | 23.1 | 24.5 | 24.9 | 0.4 |
| Firstborn | *** | *** | *** | *** | *** | *** | *** | *** | *** |

** no observations

*** not significant

**Table 4.1 Twins and Triplets: Survived and Died by Birthweight**

| Birthweight | Survived | Percent Survived | Died | Percent Died |
|---|---|---|---|---|
| **Under 1,500 grams** | 34,259 | 10.9 | 1,776 | 82.5 |
| **1,500 - 2,499 grams** | 138,337 | 44.4 | 277 | 12.9 |
| **2,500 - 3,999 grams** | 138.583 | 44.5 | 96 | 4.5 |
| **4,000+ grams** | 439 | 0.1 | 3 | 0.1 |
| **Total** | 173,174 | 99.9 | 2,152 | 100 |

**Table 4.2 Mean and Standard Deviation for Independent Variables, Twins**

| Variable | Mean, All Fetuses | Standard Deviation, All Fetuses | Mean, Fetus Survived | Standard Deviations, Fetus Survived | Mean, Fetus Died | Standard Deviation, Fetus Died |
|---|---|---|---|---|---|---|
| Very Low Birthweight | 0.106 | 0.308 | 0.101 | 0.302 | 0.822 | 0.382 |
| Low Birthweight | 0.436 | 0.496 | 0.438 | 0.496 | 0.131 | 0.338 |
| Optimal Birthweight | 0.456 | 0.498 | 0.459 | 0.498 | 0.045 | 0.208 |
| Over Birthweight | 0.0015 | 0.038 | 0.001 | 0.038 | 0.001 | 0.038 |
| Gestational Age | 35.435 | 3.725 | 36 | 3.634 | 27 | 6.042 |
| Hispanic | 0.139 | 0.346 | 0.14 | 0.347 | 0.075 | 0.264 |
| Non-Hispanic White | 0.683 | 0.465 | 0.683 | 0.465 | 0.668 | 0.471 |
| Non-Hispanic Black | 0.1773 | 0.382 | 0.177 | 0.381 | 0.257 | 0.437 |
| Age of Mother | 29 | 6.102 | 29 | 6.098 | 27 | 6.367 |
| Parity | 2.532 | 1.371 | 2.54 | 1.366 | 1.251 | 1.5 |
| Male | 0.503 | 0.5 | 0.5 | 0.5 | 0.514 | 0.5 |
| Firstborn | 0.505 | 0.5 | 0.506 | 0.5 | 0.344 | 0.475 |

**Table 4.3 Mean and Standard Deviation for Independent Variables, Triplets**

| Variable | Mean, All Fetuses | Standard Deviation, All Fetuses | Mean, Fetus Survived | Standard Deviations, Fetus Survived | Mean, Fetus Died | Standard Deviation, Fetus Died |
|---|---|---|---|---|---|---|
| Very Low Birthweight | 0.343 | 0.475 | 0.339 | 0.473 | 0.889 | 0.316 |
| Low Birthweight | 0.59 | 0.492 | 0.595 | 0.491 | 0.081 | 0.274 |
| Optimal Birthweight | 0.067 | 0.2492 | 0.067 | 0.25 | 0.03 | 0.172 |
| Over Birthweight | 0 | 0 | 0 | 0 | 0 | 0 |
| Gestational Age | 32 | 5.114 | 32 | 3.795 | 26 | 5.048 |
| Hispanic | 0.077 | 0.266 | 0.077 | 0.266 | 0.051 | 0.22 |
| Non-Hispanic White | 0.845 | 0.361 | 0.846 | 0.361 | 0.808 | 0.396 |
| Non-Hispanic Black | 0.078 | 0.268 | 0.077 | 0.267 | 0.141 | 0.35 |
| Age of Mother | 32 | 5.114 | 32 | 5.099 | 30 | 6.46 |
| Parity | 3 | 3.851 | 2.601 | 1.321 | 1.364 | 1.425 |
| Male | 0.5 | 0.5 | 0.501 | 0.5 | 0.535 | 0.502 |
| Firstborn | 0.328 | 5.11 | 0.33 | 0.47 | 0.222 | 0.418 |

**Table 4.4 The Effects of Birthweight and Gestational Age on the Hazard of Fetal Death: Twins, Model 1**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 1.499* | 0.13 | 4.47 | 347 |
| Low Birthweight | .277* | 0.122 | 1.32 | 32 |
| Over Birthweight | 2.599* | 0.587 | 13.41 | 1241.4 |
| Gestational Age | -.318* | 0.007 | 0.73 | -27.3 |
| Model $c^2$ | 8398.14* | | | |
| (Pseudo) $R^2$ | 0.0024 | | | |

* significant at .05 level

**Table 4.5 The Effects of Birthweight and Gestational Age, and the Characteristics of the Mother on the Hazard of Fetal Death: Twins, Model 2**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 1.397* | 0.132 | 4.05* | 9305.2 |
| Low Birthweight | 0.202 | 0.123 | 1.22 | *** |
| Over Birthweight | 2.754* | 0.587 | 9.17* | 817.4 |
| Gestational Age | -.293* | 0.008 | .74* | -25.4 |
| Hispanic | .370* | 0.086 | .69* | -31.0 |
| Non-Hispanic Black | 0.078 | 0.054 | 1.08 | *** |
| Age of Mother | 0.004 | 0.004 | 1.00 | *** |
| Parity | -1.167* | 0.032 | .311* | -68.9 |
| Model $c^2$ | 10441.20* | | | |
| (Pseudo) $R^2$ | .0024* | | | |

* significant at .05 level

*** not significant

**Table 4.6 The Effects of the Birthweight and Gestational Age, and the Characteristics of the Mother, and the Sex and Birth-Order of the Multiple on the Hazard of Fetal Death: Twins, Model 3**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 1.389* | 0.131 | 4.01 | 301.0 |
| Low Birthweight | 0.206 | 0.122 | 1.23 | 23 |
| Over Birthweight | 2.764* | 0.587 | 15.87 | 1486.8 |
| Gestational Age | -.286* | 0.008 | 0.75 | -24.8 |
| Hispanic | -.350* | 0.086 | 0.71 | -29.5 |
| Non-Hispanic Black | .121* | 0.054 | 1.13 | 12.8 |
| Age of Mother | .008* | 0.004 | 1.01 | 0.8 |
| Parity | -1.371* | 0.03 | 0.25 | -74.6 |
| Male | -0.018 | 0.442 | .981 | -1.9 |
| Firstborn | -1.389* | 0.047 | 0.25 | -75.1 |
| Model $c^2$ | 11352.03* | | | |
| (Pseudo) $R^2$ | 0.0024 | | | |

* significant at .05 level

*** not significant

**Table 4.7 The Relative Effect of the Independent Variables on the Hazard of Fetal Death: Twins, Model 4**

| **Variable Hazard,** | **Standardized Percent Change** |
|---|---|
| Very Low Birthweight | 53.4* |
| Low Birthweight | 13.7 |
| Over Birthweight | 11.1* |
| Gestational Age | -65.5* |
| Hispanic | -11.4* |
| Non-Hispanic Black | 4.7* |
| Age of Mother | 5.0* |
| Parity | -84.7* |
| Male | -.9 |
| Firstborn | -50.1* |

* significant at .05 level

**Table 4.8 The Effects of Birthweight and Gestational Age on the Hazard of Fetal Death: Triplets, Model 1**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | -1.132 | 0.645 | .322 | -67.8 |
| Low Birthweight | -2.070* | 0.681 | 0.13 | -87.4 |
| Over Birthweight | ** | ** | ** | ** |
| Gestational Age | -4.000* | 0.033 | 0.67 | -32.9 |
| Model $c^2$ | 297.77* | | | |
| (Pseudo) $R^2$ | 0.0182 | | | |

*significant at .05 level
** too few cases to calculate

**Table 4.10 The Effects of Birthweight and Gestational Age, and the Characteristics of the Mother, and the Sex and Birth-Order of the Fetus on the Hazard of Fetal Death: Triplets, Model 3**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 1.038 | 0.664 | .35 | -64.6 |
| Low Birthweight | -1.955* | 0.684 | 0.14 | -85.8 |
| Over Birthweight | ** | ** | ** | ** |
| Gestational Age | -.353* | 0.035 | 0.70 | -29.7 |
| Hispanic | -0.414 | 0.464 | .66 | -33.9 |
| Non-Hispanic Black | .711* | 0.295 | 2.04 | 103.5 |
| Age of Mother | 0.010 | 0.019 | 1.01 | 1.0 |
| Parity | -1.512* | 0.134 | 0.22 | -77.6 |
| Male | 0.042 | 0.203 | 1.04 | 4.0 |
| Firstborn | -1.731* | 0.25 | 0.18 | -82.3 |
| Model $c^2$ | 456.51* | | | |
| (Pseudo) $R^2$ | .0182* | | | |

*significant at .05 level
** too few cases to calculate

**Table 4.11 The Relative Effect of the Variables on the Hazard of Fetal Death: Triplets, Model 4**

| Variable | Standardized Hazard, Percent Change |
|---|---|
| Very Low Birthweight | 63.7 |
| Low Birthweight | -61.8* |
| Over Birthweight | ** |
| Gestational Age | 83.6* |
| Hispanic | -10.4 |
| Non-Hispanic Black | 20.9* |
| Age of Mother | 5.2 |
| Parity | -99.7* |
| Male | 2.1 |
| Firstborn | -99.9* |

* significant at .05 level
**too few cases to analyze

**Table 4.12 The Effects of Plurality, Birthweight and Gestational Age on the Hazard of Fetal Death: Twins and Triplets, Model 1**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Plurality | -.689* | 0.103 | 0.50 | -49.8 |
| Very Low Birthweight | 1.431* | 0.127 | 4.18 | 317.9 |
| Low Birthweight | 0.231 | 0.121 | 1.26 | 26.0 |
| Over Birthweight | 2.572* | 0.586 | 13.10 | 1209.7 |
| Gestational Age | .322* | 0.007 | 0.72 | -27.6 |
| Model $c^2$ | 8684.77* | | | |
| (Pseudo) $R^2$ | 0 | | | |

*significant at .05 level

**Table 4.13 The Effects of Plurality, Birthweight and Gestational Age, and the Characteristics of the Mother on the Hazard of Fetal Death: Twins and Triplets, Model 2**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Plurality | -.510* | 0.104 | 0.61 | -40.0 |
| Very Low Birthweight | 1.333* | 0.129 | 3.79 | 279.2 |
| Low Birthweight | 0.154 | 0.121 | 1.17 | 16.6 |
| Over Birthweight | 2.726* | 0.586 | 15.27 | 1426.5 |
| Gestational Age | -.297* | 0.007 | 0.74 | -25.7 |
| Hispanic | -.368* | 0.084 | 0.69 | -30.8 |
| Non-Hispanic Black | 0.088 | 0.053 | 1.09 | 9.2 |
| Age of Mother | 0.004 | 0.004 | 1.0 | .4 |
| Parity | -1.166* | 0.031 | 0.31 | -68.8 |
| Model $c^2$ | 8684.77* | | | |
| (Pseudo) $R^2$ | .0001* | | | |

*significant at .05 level
** too few cases to calculate

**Table 4.14 The Effects of Plurality, Birthweight and Gestational Age, and the Characteristics of the Mother, and the Sex and Birth-Order of the Fetus on the Hazard of Fetal Death: Twins and Triplets, Model 3**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Plurality | .607* | 0.104 | 0.55 | -45.5 |
| Very Low Birthweight | 1.323* | 0.129 | 0.38 | -62.5 |
| Low Birthweight | 0.161 | 0.121 | 1.17 | 17.4 |
| Over Birthweight | 2.742* | 0.586 | 15.48 | 1447.7 |
| Gestational Age | -.289* | 0.007 | 0.75 | -25.1 |
| Hispanic | -.351* | 0.084 | 0.70 | -29.6 |
| Non-Hispanic Black | .133* | 0.053 | 1.14 | 14.2 |
| Age of Mother | .008* | 0.003 | 1.01 | 0.8 |
| Parity | 1.375* | 0.03 | 0.25 | -74.7 |
| Male | -0.016 | 0.043 | .98 | -1.6 |
| Firstborn | -1.481* | 0.047 | 0.25 | -75.4 |
| Model c2 | 11796.94* | | | |
| (Pseudo) R2 | 0.0001* | | | |

*significant at .05 level

**Table 4.15 The Relative Effect of the Independent Variables on the Hazard of Fetal Death: Twins and Triplets, Model 4**

| Variable | Standardized Hazard, Percent Change |
|---|---|
| Plurality | 12.0* |
| Very Low Birthweight | 52.5* |
| Low Birthweight | 8.3 |
| Over Birthweight | 11.0* |
| Gestational Age | 66.5* |
| Hispanic | -11.4* |
| Non-Hispanic Black | 5.2* |
| Age of Mother | 5.0* |
| Parity | 557.8* |
| Male | -.8 |
| Firstborn | -52.3* |

*significant at .05 level

**Table 5.1 Twins and Triplets: Numbers Survived and Died by Birthweight**

| Birthweight | Survived | Percent Survived | Died | Percent Died |
|---|---|---|---|---|
| **Under 1,500 grams** | 27,696 | 80.8 | 6,563 | 19.2 |
| **1,500 - 2,499 grams** | 137,793 | 99.6 | 541 | 0.4 |
| **2,500 - 3,999 grams** | 138,402 | 99.9 | 181 | 0.1 |
| **4,000+ grams** | 431 | 98.2 | 8 | 1.8 |
| **Total** | 304,322 | 97.7 | 7,296 | 2.3 |

**Table 5.2 Mean and Standard Deviations for Independent Variables, Twins**

| Variable | Means, All Neonates | Standard Deviations, All Neonates | Means, Neonates Survived | Standard Deviations, Neonate Survived | Means, Neonate Died | Standard Deviations, Neonates Died |
|---|---|---|---|---|---|---|
| Very Low Birthweight | .101 | .302 | .083 | .276 | .893 | .309 |
| Low Birthweight | .438 | .96 | .447 | .97 | .079 | .269 |
| Optimal Birthweight | .459 | .498 | .469 | .499 | .027 | .062 |
| Over Birthweight | .001 | .38 | .001 | .038 | .001 | .034 |
| Gestational Age | 35.495 | 3.4 | 35.724 | 3.261 | 25.481 | 4.797 |
| Hispanic | .139 | .347 | .139 | .347 | .2 | .339 |
| Non-Hispanic White | .683 | .465 | .686 | .464 | .579 | .494 |
| Non-Hispanic Black | .177 | .381 | .174 | .379 | .288 | .453 |
| Age of Mother | 28.806 | 6.098 | 28.848 | 6.087 | 26.939 | 6.291 |
| Parity | 2.54 | 1.366 | 2.545 | 1.365 | 2.346 | .413 |
| Male | .503 | .5 | .502 | .5 | .545 | .498 |
| Firstborn | .506 | .499 | .505 | .499 | .539 | .499 |

**Table 5.3 Mean and Standard Deviation for Independent Variables, Triplets**

| Variable | Means, All Neonates | Standard Deviations, All Neonates | Means, Neonates Survived | Standard Deviations, Neonate Survived | Means, Neonate Died | Standard Deviations, Neonate Died |
|---|---|---|---|---|---|---|
| Very Low Birthweight | .339 | .473 | .304 | .460 | .971 | .169 |
| Low Birthweight | .595 | .491 | .625 | .484 | .028 | .164 |
| Optimal Birthweight | .067 | .249 | .070 | .256 | .002 | .042 |
| Over Birthweight | 0 | 0 | 0 | 0 | 0 | 0 |
| Gestational Age | 32.204 | 3.379 | 32.642 | 3.27 | 24.136 | 3.697 |
| Hispanic | .077 | .266 | .076 | .264 | .098 | .298 |
| Non-Hispanic White | .846 | .361 | .851 | .356 | .749 | .434 |
| Non-Hispanic Black | .077 | .267 | .073 | .261 | .152 | .359 |
| Age of Mother | 31.729 | 5.099 | 31.844 | 5.058 | 29.627 | 5.392 |
| Parity | 2.601 | 1.321 | 2.608 | 1.314 | 2.463 | 1.441 |
| Male | .501 | .501 | .498 | .5 | .542 | .499 |
| Firstborn | .329 | .469 | .328 | .469 | .349 | .477 |

**Table 5.4 The Effects of Birthweight and Gestational Age on the Hazard of Neonatal Death: Twins, Model 1**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 1.928* | 0.112 | 6.88 | 587.7 |
| Low Birthweight | .276* | .100 | 1.32 | 31.8 |
| Over Birthweight | 1.132 | 1.000 | 1.32 | 31.8 |
| Gestational Age | -.278* | .006 | .76 | -24.3 |
| LR $\chi^2$ | 10280.05* | | | |
| (Pseudo) $R^2$ | .0022 | | | |

* significant at .05 level

**Table 5.5 The Effects of Birthweight and Gestational Age, and the Characteristics of the Mother on the Hazard of Neonatal Death: Twins, Model 2**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 1.924* | 0.112 | 6.85 | 585.1 |
| Low Birthweight | .271* | .104 | 1.31 | 31.1 |
| Over Birthweight | 1.132 | 1.004 | 3.10 | 210.3 |
| Gestational Age | -.28* | .006 | .76 | -24.4 |
| Hispanic | .009 | .059 | 1.01 | 1.0 |
| Non-Hispanic Black | -.241* | .049 | .79 | -21.4 |
| Age of Mother | -.019* | .003 | .98 | -1.9 |
| Parity | .036 | .003 | 1.04 | 3.6 |
| LR $\chi^2$ | 10329.74* | | | |
| (Pseudo) $R^2$ | .0022* | | | |

* significant at .05 level

*** not significant

**Table 5.6 The Effects of Birthweight and Gestational Age, and the Characteristics of the Mother, and the Sex and Birth-Order of the Neonate on the Hazard of Neonate Death: Twins, Model 3**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 1.951* | .112 | 7.03 | 603.4 |
| Low Birthweight | .290* | .105 | 1.34 | 33.7 |
| Over Birthweight | 1.104 | 1.004 | .76 | -24.3 |
| Gestational Age | .278* | .006 | .76 | 174.6 |
| Hispanic | .014 | .059 | 1.02 | 1.5 |
| Non-Hispanic Black | -.233* | .049 | .79 | -8.5 |
| Age of Mother | .018* | .003 | .98 | 11.6 |
| Parity | .036* | .015 | 1.04 | 5.0 |
| Male | .237* | .039 | 1.27 | 12.6 |
| Firstborn | .001* | .040 | 1.00 | .1 |
| LR $\chi^2$ | 10366.2* | | | |
| (Pseudo) $R^2$ | .0022 | | | |

* significant at .05 level

*** not significant

**Table 5.7 The Relative Effects of the Independent Variables on the Hazard of Neonatal Death: Twins, Model 4**

| Variable | Standardized Hazard, Percent Change |
|---|---|
| Very Low Birthweight | 79.9 |
| Low Birthweight | 15.5 |
| Over Birthweight | 4.3 |
| Gestational Age | 174.6 |
| Hispanic | 0.5 |
| Non-Hispanic Black | -8.5 |
| Age of Mother | 11.6 |
| Parity | 5.0 |
| Male | 12.6 |
| Firstborn | 0.1 |

* significant at .05 level

**Table 5.8 The Effects of Birthweight and Gestational Age on the Hazard of Neonatal Death: Triplets, Model 1**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | .798 | 1.019 | 2.22 | 122.2 |
| Low Birthweight | -.46 | 1.037 | .63 | -36.9 |
| Over Birthweight | *** | *** | *** | *** |
| Gestational Age | -.411* | .023 | .66 | -33.7 |
| LR $\chi^2$ | 673.81* | | | |
| (Pseudo) $R^2$ | .0179 | | | |

*significant at .05 level
** too few cases to calculate

**Table 5.9 The Effects of Birthweight and Gestational Age, and the Characteristics of the Mother on the Hazard of Neonatal Death: Triplets, Model 2**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | .749 | 1.02 | 2.1 | -111.6 |
| Low Birthweight | -0.496 | 1.037 | .61 | 39.1 |
| Over Birthweight | *** | *** | *** | *** |
| Gestational Age | -.405* | .023 | .67 | 33.3 |
| Hispanic | .223 | .231 | 1.25 | -25.0 |
| Non-Hispanic Black | .247 | .203 | 1.28 | -28.1 |
| Age of Mother | -.022 | .013 | .98 | 2.2 |
| Parity | .029 | .052 | 1.03 | -2.9 |
| LR $\chi^2$ | 680.33* | | | |
| (Pseudo) $R^2$ | .018* | | | |

*significant at .05 level
** too few cases to calculate

**Table 5.10 The Effects of Birthweight and Gestational Age, and the Characteristics of the Mother, and the Sex and Birth-Order of the Neonate on the Hazard of Neonatal Death: Triplets, Model 3**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | .811 | 1.02 | 2.23 | 122.5 |
| Low Birthweight | -.469 | 1.03 | .63 | -37.5 |
| Over Birthweight | *** | *** | *** | *** |
| Gestational Age | .402* | .023 | .67 | -33.1 |
| Hispanic | .213 | .213 | 1.24 | 23.7 |
| Non-Hispanic Black | .246 | .204 | 1.28 | 28.0 |
| Age of Mother | -.023 | .013 | .98 | -2.3 |
| Parity | .054 | .056 | 1.06 | 5.6 |
| Male | .188 | .141 | 1.211 | 20.7 |
| Firstborn | .162 | .162 | 1.18 | 17.6 |
| LR $\chi^2$ | 682.92 | | | |
| (Pseudo) $R^2$ | .018 | | | |

*significant at .05 level
** too few cases to calculate

**Table 5.11 The Relative Effects of the Independent Variables on the Hazard of Neonatal Death: Triplets, Model 4**

| Variable | Standardized Hazard, Percent Change |
|---|---|
| Very Low Birthweight | 45.9 |
| Low Birthweight | -20.6 |
| Over Birthweight | *** |
| Gestational Age | 360.7* |
| Hispanic | 5.8 |
| Non-Hispanic Black | 6.8 |
| Age of Mother | -11.1 |
| Parity | 7.3 |
| Male | 9.9 |
| Firstborn | 7.9 |

* significant at .05 level
**too few cases to analyze

**Table 5.12 The Effects of Plurality, Birthweight and Gestational Age on the Hazard of Neonatal Death: Twins and Triplets, Model 1**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Plurality | .222* | .072 | .80 | -19.9 |
| Very Low Birthweight | 1.839* | .108 | 6.29 | 529 |
| Low Birthweight | .233* | .104 | 1.26 | 26.3 |
| Over Birthweight | 1.139 | 1.004 | 3.12 | 212.3 |
| Gestational Age | -.287* | 1.004 | .75 | -25.0 |
| LR $\chi^2$ | 1116.34* | | | |
| (Pseudo) $R^2$ | 0 | | | |

*significant at .05 level

**Table 5.13 The Effects of Plurality, Birthweight and Gestational Age, and the Characteristics of the Mother on the Hazard of Neonatal Death: Twins and Triplets, Model 2**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Plurality | .201* | .073 | .82 | -18.2 |
| Very Low Birthweight | 1.837* | .108 | 6.28 | 528.1 |
| Low Birthweight | .23* | .104 | 1.26 | 25.8 |
| Over Birthweight | 1.138 | 1.004 | 3.12 | 212.1 |
| Gestational Age | -.288* | .006 | .75 | -25.1 |
| Hispanic | .024 | .057 | 1.02 | 2.4 |
| Non-Hispanic Black | -.225* | .048 | .79 | -20.1 |
| Age of Mother | -.019* | .003 | .98 | -1.9 |
| Parity | .036* | .014 | 1.04 | 3.7 |
| LR $\chi^2$ | 11068.04 | | | |
| (Pseudo) $R^2$ | .0001* | | | |

*significant at .05 level
** too few cases to calculate

**Table 5.14 The Effects Plurality, Birthweight and Gestational Age, the Characteristics of the Mother, and the Sex and Birth-Order of the Neonate on the Hazard of Neonatal Death: Twins and Triplets, Model 3**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Plurality | -.2* | .074 | .82 | -18.1 |
| Very Low Birthweight | 1.866* | .108 | 6.46 | 546 |
| Low Birthweight | .249* | .104 | 1.28 | 28.2 |
| Over Birthweight | 1.11 | 1.004 | 3.034 | 203.4 |
| Gestational Age | -.287* | .006 | .75 | -24.9 |
| Hispanic | .028 | .057 | 1.03 | 2.9 |
| Non-Hispanic Black | -.217* | .048 | .81 | -19.5 |
| Age of Mother | -.019* | .003 | .98 | -1.9 |
| Parity | .371* | .014 | 1.04 | 3.8 |
| Male | .235* | .038 | 1.27 | 26.5 |
| Firstborn | .008 | .039 | 1.01 | 0.8 |
| LR $\chi^2$ | 11106.74 | | | |
| (Pseudo) R2 | .0001 | | | |

*significant at .05 level

**Table 5.15 The Relative Effects of the Independent Variables on the Hazard of Neonatal Death: Twins and Triplets, Model 4**

| **Variable** | **Standardized Hazard, Percent Change** |
|---|---|
| Parity | -3.3 |
| Very Low Birthweight | 79.3 |
| Low Birthweight | 13.2 |
| Over Birthweight | 4.3 |
| Gestational Age | -65.3 |
| Hispanic | 1.0 |
| Non-Hispanic Black | -7.9 |
| Age of Mother | -10.9 |
| Parity | 65.9 |
| Male | 12.5 |
| Firstborn | 0.4 |

*significant at .05 level

**Table 6.1 Twins and Triplets: Survived and Died by Birthweight**

| Birthweight | Survived | Percent Survived | Died | Percent Died |
|---|---|---|---|---|
| **Under 1,500 grams** | 26,864 | 97.0 | 832 | 3.0 |
| **1,500 - 2,499 grams** | 137,198 | 99.5 | 595 | .4 |
| **2,500 - 3,999 grams** | 138,117 | 99.8 | 285 | .2 |
| **4,000+ grams** | 427 | 99.1 | 4 | .9 |
| **Total** | 304,322 | 99.4 | 1716 | .6 |

**6.2 Mean and Standard Deviation for Independent Variables, Twins**

| Variable | Mean, All Postneonates | Standard Deviation, All Postneonates | Mean, Postneonates Survived | Standard Deviations, Postneonates Survived | Mean, Postneonates Died | Standard Deviation, Postneonates Died |
|---|---|---|---|---|---|---|
| Very Low Birthweight | .083 | .276 | .273 | .499 | .083 | .276 |
| Low Birthweight | .447 | .497 | .497 | .487 | .447 | .497 |
| Optimal Birthweight | .469 | .499 | .499 | .378 | .469 | .499 |
| Over Birthweight | .001 | .038 | .038 | .049 | .001 | .038 |
| Gestational Age | 35.724 | 3.261 | 3.233 | 5.199 | 36 | 3.261 |
| Hispanic | .139 | .347 | .347 | .325 | .140 | .347 |
| Non-Hispanic White | .686 | .464 | .464 | .499 | .686 | .464 |
| Non-Hispanic Black | .174 | .379 | .378 | .478 | .174 | .379 |
| Age of Mother | 29 | 6.087 | 29 | 6.352 | 29 | 6.087 |
| Parity | 2.5445 | 1.365 | 1.364 | 1.549 | 2.545 | 1.365 |
| Male | .502 | .499 | .499 | .498 | .502 | .5 |
| Firstborn | .505 | .499 | .499 | .500 | .505 | .5 |

**Table 6.3 Mean and Standard Deviation for Independent Variables, Triplets**

| Variable | Mean, All Postneonates | Standard Deviation, All Postneonates | Mean, Postneonates Survived | Standard Deviations, Postneonates Survived | Mean, Postneonates Died | Standard Deviation, Postneonates Died |
|---|---|---|---|---|---|---|
| Very Low Birthweight | .304 | .460 | .301 | .459 | .795 | .407 |
| Low Birthweight | .625 | .484 | .483 | .483 | .178 | .385 |
| Optimal Birthweight | .070 | .256 | .256 | .256 | .027 | .164 |
| Over Birthweight | 0 | 0 | 0 | 0 | 0 | 0 |
| Gestational Age | 33 | 3.274 | 33 | 3.259 | 29 | 3.739 |
| Hispanic | .076 | .264 | .076 | .265 | .055 | .229 |
| Non-Hispanic White | .851 | .356 | .355 | .355 | .712 | .456 |
| Non-Hispanic Black | .073 | .261 | .072 | .259 | .233 | .426 |
| Age of Mother | 32 | 5.058 | 32 | 5.051 | 31 | 5.848 |
| Parity | 2.608 | 1.314 | 1.314 | 1.314 | 2.726 | 1.397 |
| Male | .498 | .500 | .498 | 5.00 | .493 | .503 |
| Firstborn | .328 | .469 | .328 | .469 | .328 | .473 |

**Table 6.4 The Effects of Birthweight and Gestational Age on the Hazard of Postneonatal Death: Twins, Model 1**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 2.619* | .103 | 5.048 | 404.8 |
| Low Birthweight | .461* | .076 | 1.586 | 58.6 |
| Over Birthweight | 1.638* | .504 | 5.144 | 414.4 |
| Gestational Age | -.133* | .006 | .875 | -12.5 |
| LR $\chi^2$ | 2118.49* | | | |
| (Pseudo) $R^2$ | .0016* | | | |

* significant at .05 level

**Table 6.5 The Effects of Birthweight and Gestational Age, and the Characteristics of the Mother on the Hazard of Postneonatal Death: Twins, Model 2**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 1.558* | .102 | 4.752 | 375.2 |
| Low Birthweight | .415* | .076 | 1.515 | 51.5 |
| Over Birthweight | 1.621* | .504 | 5.049 | 404.9 |
| Gestational Age | -.124* | .008 | .884 | -11.6 |
| Hispanic | -.119 | .08 | .888 | -11.2 |
| Non-Hispanic Black | .328* | .058 | 1.388 | 38.8 |
| Age of Mother | -.059* | .004 | .943 | -5.7 |
| Parity | .172* | .016 | 1.187 | 18.7 |
| LR $\chi^2$ | 2471.88* | | | |
| (Pseudo) $R^2$ | .0016* | | | |

* significant at .05 level

**Table 6.6 The Effects of Birthweight and Gestational Age, and the Characteristics of the Mother, and the Sex and Birth-Order of the Multiple on the Hazard of Postneonatal Death: Twins, Model 3**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 1.591* | .103 | 4.908 | 390.8 |
| Low Birthweight | .435* | .076 | 1.546 | 54.6 |
| Over Birthweight | 1.586* | .504 | 4.882 | 388.2 |
| Gestational Age | -.122* | .008 | .885 | -11.5 |
| Hispanic | -.121* | .081 | .886 | -11.4 |
| Non-Hispanic Black | .325* | .058 | 1.383 | 38.3 |
| Age of Mother | -.059* | .004 | .942 | -5.8 |
| Parity | .179* | .017 | 1.196 | 19.6 |
| Male | .196* | .05 | 1.217 | 21.7 |
| Firstborn | .093 | .051 | .056 | -94.4 |
| LR $\chi^2$ | 2490.85* | | | |
| (Pseudo) $R^2$ | .0016 | | | |

* significant at .05 level

**Table 6.7 The Relative Effect of all the Independent Variables on the Hazard of Postneonatal Death: Twins, Model 4**

| Variable | Standardized Hazard, Percent Change |
|---|---|
| Very Low Birthweight | 55.134* |
| Low Birthweight | 24.134* |
| Over Birthweight | 6.212* |
| Gestational Age | -32.823* |
| Hispanic | 4.288* |
| Non-Hispanic Black | 13.108* |
| Age of Mother | -31.172* |
| Parity | 27.677* |
| Male | 10.296* |
| Firstborn | 4.760 |

* significant at .05 level

**Table 6.8 The Effects of Birthweight and Gestational Age on the Hazard of Postneonatal Death: Triplets, Model 1**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | .966 | .772 | 2.628 | `162.8 |
| Low Birthweight | -.616 | .765 | .540 | -46 |
| Over Birthweight | ** | ** | ** | ** |
| Gestational Age | -.146* | .041 | .864 | -13.6 |
| LR $\chi^2$ | 88.34* | | | |
| (Pseudo) $R^2$ | .016 | | | |

*significant at .05 level
** too few cases to calculate

**Table 6.9 The Effects of Birthweight and Gestational Age, and the Characteristics of the Mother on the Hazard of Postneonatal Death: Triplets, Model 2**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | .853 | .774 | 2.359 | 135.9 |
| Low Birthweight | -.674 | .765 | .509 | -49.1 |
| Over Birthweight | ** | ** | ** | ** |
| Gestational Age | -.141* | .041 | .868 | 13.2 |
| Hispanic | .235 | .522 | .790 | -21 |
| Non-Hispanic Black | .985* | .295 | 2.678 | 167.8 |
| Age of Mother | -.016 | .022 | .984 | -1.6 |
| Parity | .049 | .086 | 1.051 | 5.1 |
| LR $\chi^2$ | 101.43* | | | |
| (Pseudo) $R^2$ | .016* | | | |

*significant at .05 level
** too few cases to calculate

**Table 6.10 The Effects of Birthweight and Gestational Age, and the Characteristics of the mother, and the Sex and Birth-Order of the Multiple on the Hazard of Postneonatal Death: Triplets, Model 3**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | .882 | .776 | 2.42 | 142 |
| Low Birthweight | -.662 | .766 | .516 | -48.4 |
| Over Birthweight | ** | ** | ** | ** |
| Gestational Age | -.140* | .041 | .869 | -13.1 |
| Hispanic | -.241 | .522 | .786 | -21.4 |
| Non-Hispanic Black | .972* | .297 | 2.643 | 164.3 |
| Age of Mother | 0.017 | .022 | .984 | -1.6 |
| Parity | .066 | .092 | 1.068 | 6.8 |
| Male | .048 | .236 | 1.049 | 4.9 |
| Firstborn | .124 | .271 | 1.132 | 13.2 |
| LR $\chi^2$ | 101.67* | | | |
| (Pseudo) $R^2$ | .161* | | | |

*significant at .05 level
** too few cases to calculate

**Table 6.11 The Relative Effect of the Independent Variables on the Hazard of Postneonatal Death: Triplets, Model 4**

| Variable | Standardized Hazard, Percent Change |
|---|---|
| Very Low Birthweight | 50.038 |
| Low Birthweight | -27.415 |
| Over Birthweight | ** |
| Gestational Age | -36.768* |
| Hispanic | -6.164 |
| Non-Hispanic Black | 28.877* |
| Age of Mother | 8.979 |
| Parity | 9.060 |
| Male | 2.429 |
| Firstborn | 6.001 |

significant at the .05 level
** too few cases

**Table 6.12 The Effects of Plurality, Birthweight and Gestational Age on the Hazard of Postneonatal Death: Twins and Triplets, Model 1**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Plurality | -.614* | .121 | .541 | -.45.9 |
| Very Low Birthweight | 1.622* | .102 | 5.067 | 406.7 |
| Low Birthweight | .448* | .075 | 1.565 | 56.5 |
| Over Birthweight | 1.634* | .504 | 5.126 | 412.6 |
| Gestational Age | -.133* | .008 | .875 | -12.5 |
| LR $\chi^2$ | 2206.01* | | | |
| (Pseudo) $R^2$ | .0001* | | | |

*significant at .05 level

**Table 6.13 The Effects of Plurality, Birthweight and Gestational Age, and the Characteristics of the Mother on the Hazard of Postneonatal Death: Twins and Triplets, Model 2**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Plurality | -.357* | .122 | .711 | 30.1 |
| Very Low Birthweight | 1.561* | .101 | 4.762 | 376.2 |
| Low Birthweight | .401* | .075 | 1.494 | 49.4 |
| Over Birthweight | 1.616* | .504 | 5.034 | 403.4 |
| Gestational Age | -.124* | .008 | .884 | -11.6 |
| Hispanic | -.116 | .079 | .891 | -10.9 |
| Non-Hispanic Black | 35* | .057 | 1.419 | 41.9 |
| Age of Mother | -.057* | .004 | .045 | -5.5 |
| Parity | .166* | .016 | 1.181 | 18.1 |
| LR $\chi^2$ | 2564.64* | | | |
| (Pseudo) $R^2$ | .0001* | | | |

*significant at .05 level

**Table 6.14 The Effects of Plurality, Birthweight and Gestational Age, and the Characteristics of the Mother, and the Sex and Birth-Order of the Multiple on the Hazard of Postneonatal Death: Twins and Triplets, Model 3**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Plurality | -.337* | .122 | .714 | -28.6 |
| Very Low Birthweight | 1.593* | .101 | 4.917 | 391.7 |
| Low Birthweight | .421* | .075 | 1.523 | 52.3 |
| Over Birthweight | 1.583* | .504 | 4.872 | 387.2 |
| Gestational Age | -.122* | .008 | .886 | -11.4 |
| Hispanic | -.118 | .079 | .888 | -11.2 |
| Non-Hispanic Black | .346* | .057 | 1.414 | 41.4 |
| Age of Mother | -.057* | .004 | .944 | -5.6 |
| Parity | .174* | .016 | 1.19 | 19.0 |
| Male | .19* | .049 | 1.209 | 20.9 |
| Firstborn | .096 | .05 | 1.101 | 10.1 |
| LR $\chi^2$ | 2583.55 | | | |
| (Pseudo) R2 | .0001 | | | |

*significant at .05 level

**Table 6.15 The Relative Effects of all the Independent Variables on the Hazard of Postneonatal Death: Twins and Triplets, Model 4**

| Variable | Standardized Hazard, Percent Change |
|---|---|
| Parity | -6.012* |
| Very Low Birthweight | 58.215* |
| Low Birthweight | 23.326* |
| Over Birthweight | 6.200* |
| Gestational Age | 49.772* |
| Hispanic | -11.130 |
| Non-Hispanic Black | 13.894* |
| Age of Mother | -29.284* |
| Parity | 26.765* |
| Male | 9.966* |
| Firstborn | 4.917 |

*signficiant at .05 level

**Table 7.1 Twins and Triplets: Survived and Died by Birthweight**

| Birthweight | Survived | Percent Survived | Died | Percent Died |
|---|---|---|---|---|
| **Under 1,500 grams** | 26,864 | 78.4 | 7,395 | 21.6 |
| **1,500 - 2,499 grams** | 137,198 | 99.2 | 1,139 | .8 |
| **2,500 - 3,999 grams** | 138,117 | 99.7 | 466 | .3 |
| **4,000+ grams** | 427 | 97.3 | 12 | 2.7 |
| **Total** | 311,618 | 97.1 | 9,012 | 2.9 |

**Table 7.2 Mean and Standard Deviation for Independent Variables, Twins**

| Variable | Mean, All Infants | Standard Deviation, All Infants | Mean, Infants Survived | Standard Deviation, Infant Survived | Mean, Infants Died | Standard Deviation, Infants Died |
|---|---|---|---|---|---|---|
| Very Low Birthweight | | .302 | .081 | .273 | .810 | .392 |
| Low Birthweight | .438 | .496 | .447 | .497 | .133 | .339 |
| Optimal Birthweight | .459 | .498 | .470 | .499 | .055 | .229 |
| Over Birthweight | .001 | .038 | .001 | .038 | .001 | .038 |
| Gestational Age | 36 | 3.634 | 35.746 | 3.233 | 26.702 | 5.468 |
| Hispanic | .139 | .347 | .140 | .347 | .130 | .336 |
| Non-Hispanic White | .683 | .465 | .687 | .464 | .569 | .495 |
| Non-Hispanic Black | .177 | .381 | .173 | .378 | .301 | .459 |
| Age of Mother | 29 | 6.099 | 28.863 | 6.082 | 26.792 | 6.310 |
| Parity | 2.540 | 1.366 | 2.544 | 1.364 | 2.431 | 1.451 |
| Male | .503 | .499 | .502 | .499 | .545 | .498 |
| Firstborn | .506 | .499 | .505 | .499 | .531 | .499 |

**Table 7.3 Mean and Standard Deviation for Independent Variables, Triplets**

| Variable | Mean, All Infants | Standard Deviation, All Infants | Mean, Infants Survived | Standard Deviation, Infant Survived | Mean, Infants Died | Standard Deviation, Infants Died |
|---|---|---|---|---|---|---|
| Very Low Birthweight | .339 | .473 | .301 | .459 | .951 | .216 |
| Low Birthweight | .595 | .491 | .62 | .483 | .044 | .206 |
| Optimal Birthweight | .067 | .249 | .071 | .256 | .005 | .068 |
| Over Birthweight | 0 | 0 | 0 | 0 | 0 | 0 |
| Gestational Age | 32 | 3.795 | 33 | 3.259 | 25 | 4.047 |
| Hispanic | .077 | .266 | .076 | .265 | .094 | .291 |
| Non-Hispanic White | .846 | .361 | .852 | .355 | .745 | .436 |
| Non-Hispanic Black | .077 | .267 | .072 | .259 | .161 | .368 |
| Age of Mother | 32 | 5.099 | 32 | 5.051 | 30 | 5.449 |
| Parity | 2.601 | 1.321 | 2.607 | 1.314 | 2.492 | 1.437 |
| Male | .501 | .500 | .498 | .500 | .537 | .499 |
| Firstborn | .329 | .469 | .328 | .469 | .347 | .476 |

**Table 7.4 The Effects of Birthweight and Gestational Age on the Hazard of Infant Death: Twins, Model 1**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 1.624* | .071 | 5.075 | 407.5 |
| Low Birthweight | .281* | .061 | 1.324 | 32.4 |
| Over Birthweight | 1.557* | .45 | .4.747 | 3.747 |
| Gestational Age | -.228* | .005 | .796 | -20.4 |
| LR $\chi^2$ | 11711.32* | | | |
| (Pseudo) $R^2$ | .0022* | | | |

* significant at .05 level

**Table 7.5 The Effects of Birthweight and Gestational Age, and the Characteristics of the Mother on the Hazard of Infant Death: Twins, Model 2**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 1.622* | .071 | 5.062 | 406.2 |
| Low Birthweight | .27* | .061 | 1.309 | 30.9 |
| Over Birthweight | 1.545* | .45 | 4.687 | 368.7 |
| Gestational Age | -.223* | .005 | .8 | -20 |
| Hispanic | -.03 | .047 | .97 | -3.0 |
| Non-Hispanic Black | -.012 | .003 | .967 | -3.3 |
| Age of Mother | -.034* | .003 | .967 | -3.3 |
| Parity | .099* | .011 | 1.09 | 9 |
| LR $\chi^2$ | 11920.01* | | | |
| (Pseudo) $R^2$ | .0022* | | | |

* significant at .05 level

**Table 7.6 The Effects of the Birthweight and Gestational Age, and the characteristics of the Mother, and the Sex and Birth-Order of the Multiple on the Hazard of Infant Death: Twins, Model 3**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | 1.651* | .071 | 5.215 | 421.5 |
| Low Birthweight | .289* | .061 | 1.335 | 33.5 |
| Over Birthweight | 1.514* | .45 | 4.547 | 354.7 |
| Gestational Age | -222* | .005 | .801 | -19.9 |
| Hispanic | -.028 | .047 | .970 | -3.0 |
| Non-Hispanic Black | -.008 | .003 | .967 | -3.3 |
| Age of Mother | -.034* | .003 | .967 | -3.3 |
| Parity | .09* | .011 | 1.097 | 9.7 |
| Male | .222* | .031 | 1.249 | 24.9 |
| Firstborn | .039 | .032 | 1.039 | 3.9 |
| LR $\chi^2$ | 11973.42 | | | |
| (Pseudo) $R^2$ | .0022* | | | |

* significant at .05 level

**Table 7.7 The Relative Effect of the Independent Variables on the Hazard of Infant Death: Twins, Model 4**

| Variable | Standardized Hazard, Percent Change |
|---|---|
| Very Low Birthweight | 64.642* |
| Low Birthweight | 15.413* |
| Over Birthweight | 5.922* |
| Gestational Age | -77.071* |
| Hispanic | -.967 |
| Non-Hispanic Black | -1.287 |
| Age of Mother | -18.725* |
| Parity | 13.061* |
| Male | 11.739* |
| Firstborn | 1.969 |

*significant at .05 level

**Table 7.8 The Effects of Birthweight and Gestational Age on the Hazard of Infant Death: Triplets, Model 1**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | .495 | .601 | 1.64 | 64.0 |
| Low Birthweight | -.748 | .61 | .473 | -52.7 |
| Over Birthweight | ** | ** | ** | ** |
| Gestational Age | -.346* | .02 | .707 | -29.3 |
| LR $\chi^2$ | 722.33* | | | |
| (Pseudo) $R^2$ | .0179* | | | |

* significant at .05 level
** too few cases to calculate

**Table 7.9 The Effects of Birthweight and Gestational Age, and the Characteristics of the Mother on the Hazard of Infant Death: Triplets, Model 2**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | .439 | .602 | 1.551 | 55.1 |
| Low Birthweight | -.784 | .611 | .457 | -54.3 |
| Over Birthweight | ** | ** | ** | ** |
| Gestational Age | -.340* | .02 | .712 | -28.8 |
| Hispanic | .147 | .21 | 1.159 | 15.9 |
| Non-Hispanic Black | .463* | .166 | 1.589 | 58.9 |
| Age of Mother | -.021 | .011 | .979 | -2.1 |
| Parity | .041 | .044 | 1.041 | 4.1 |
| LR $\chi^2$ | 736.95* | | | |
| (Pseudo) $R^2$ | .018* | | | |

* significant at .05 level

** too few cases to calculate

**Table 7.10 The Effects of Birthweight and Gestational Age, and the Characteristics of the Mother, and the Sex and Birth-Order of the Multiple on the Hazard of Infant Death: Triplets, Model 3**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Very Low Birthweight | .484 | .603 | 1.623 | 62.3 |
| Low Birthweight | -.76 | .611 | .468 | -53.2 |
| Over Birthweight | ** | ** | ** | ** |
| Gestational Age | -.388* | .02 | .713 | -28.7 |
| Hispanic | .138 | .211 | 1.148 | 14.8 |
| Non-Hispanic Black | .458* | .168 | 1.581 | 58.1 |
| Age of Mother | -.022 | .011 | .979 | -2.1 |
| Parity | .0617 | .048 | 1.064 | 6.4 |
| Male | .158 | .121 | 1.171 | 17.1 |
| Firstborn | .141 | .139 | 1.151 | 15.1 |
| LR $\chi^2$ | 739.53* | | | |
| (Pseudo) $R^2$ | .018* | | | |

* significant at .05 level

** too few cases to calculate

**Table 7.11 The Relative Effect of the Variables on the Hazard of Infant Death: Triplets, Model 4**

| Variable | Standardized Hazard, Percent Change |
|---|---|
| Very Low Birthweight | 25.726 |
| Low Birthweight | -31.144 |
| Over Birthweight | ** |
| Gestational Age | -72.272* |
| Hispanic | 3.739 |
| Non-Hispanic Black | 13.008* |
| Age of Mother | -10.613 |
| Parity | 8.485 |
| Male | 8.220 |
| Firstborn | 6.852 |

* significant at .05 level
** too few cases to calculate

**Table 7.12 The Effects of Plurality, Birthweight and Gestational Age on the Hazard of Infant Death: Twins and Triplets, Model 1**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Plurality | -.359* | .062 | .698 | -30.2 |
| Very Low Birthweight | 1.564* | .07 | .4779 | -52.21 |
| Low Birthweight | .244* | .06 | 1.276 | 27.6 |
| Over Birthweight | 1.561* | .45 | 4.764 | 376.4 |
| Gestational Age | -.235* | .005 | .791 | -20.9 |
| LR $\chi^2$ | 12470.75* | | | |
| (Pseudo) $R^2$ | 0 | | | |

*significant at .05 level

**Table 7.13 The Effects of Plurality, Birthweight and Gestational Age, and the Characteristics of the Mother on the Hazard of Infant Death: Twins and Triplets, Model 2**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Plurality | -.254* | .063 | .776 | -22.4 |
| Very Low Birthweight | 1.562* | .07 | 4.767 | 376.7 |
| Low Birthweight | .232* | .06 | 1.262 | 26.2 |
| Over Birthweight | 1.548* | .45 | 4.703 | 370.3 |
| Gestational Age | -.23* | .005 | .795 | -20.5 |
| Hispanic | -.018 | .046 | .983 | -1.7 |
| Non-Hispanic Black | .005 | .037 | 1.005 | 0.5 |
| Age of Mother | .033* | .003 | .968 | -3.2 |
| Parity | .087* | .011 | 1.091 | 9.1 |
| LR $\chi^2$ | 12686.42* | | | |
| (Pseudo) $R^2$ | .0001 | | | |

*significant at .05 level

**Table 7.14 The Effects of Plurality, Birthweight and Gestational Age, the Characteristics of the Mother, and the Sex and Birth-Order of the Infant on the Hazard of Infant Death: Twins and Triplets, Model 3**

| Variable | Coefficients | SE | Hazard Ratio | Percent Change |
|---|---|---|---|---|
| Plurality | -.245* | .063 | .783 | -21.7 |
| Very Low Birthweight | 1.592* | .07 | 4.914 | 28.7 |
| Low Birthweight | .252* | .061 | 1.287 | 28.7 |
| Over Birthweight | 1.518* | .45 | 4.563 | 356.3 |
| Gestational Age | -.228* | .005 | .796 | -20.4 |
| Hispanic | -.016 | .046 | .984 | -1.6 |
| Non-Hispanic Black | .008 | .037 | 1.009 | .09 |
| Age of Mother | -.033* | .003 | .968 | -3.2 |
| Parity | .091* | .011 | 1.095 | 9.5 |
| Male | .219* | .03 | 1.245 | 24.5 |
| Firstborn | .043 | .031 | 1.044 | 4.4 |
| LR $\chi^2$ | 12742.18* | | | |
| (Pseudo) $R^2$ | .0001 | | | |

*significant at .05 level

**Table 7.15 The Relative Effect of the Independent Variables on the Hazard of Infant Death: Twins and Triplets, Model 4**

| Variable | Standardized Hazard, Percent Change |
|---|---|
| Plurality | -4.455* |
| Very Low Birthweight | 64.591* |
| Low Birthweight | 13.342* |
| Over Birthweight | 5.938* |
| Gestational Age | -56.896* |
| Hispanic | -.738 |
| Non-Hispanic Black | .303 |
| Age of Mother | -18.204* |
| Parity | 13.226* |
| Male | 11.572* |
| Firstborn | 2.173 |

* significant at the .05 level

**Table 8.1 Percent Change in the Relative Effects of the Semi-Standardized Hazard Coefficients on Fetal Mortality: United States, 2000-2005**

| | Semi-Standardized Hazard, Percent Change | | |
|---|---|---|---|
| **Variable** | **Twins** | **Triplets** | **Twins & Triplets** |
| Plurality | *** | *** | 12.0* |
| Very Low Birthweight | 53.4* | -38.9 | 52.5* |
| Low Birthweight | 13.7 | -61.8* | 8.3 |
| Over Birthweight | 11.1* | ** | 10.9* |
| Gestational Age | -65.5* | 83.6* | 66.5* |
| Hispanic | -11.4* | -10.4 | -11.4* |
| Non-Hispanic Black | 4.7* | 20.9* | 5.2* |
| Age of Mother | 5.0* | 5.2 | 5.0* |
| Parity | -84.7* | -99.7* | 557.8* |
| Male | -0.9 | 2.1 | -.8* |
| Firstborn | -50.1* | -99.9* | -52.3* |

* significant at .05 level

** too few cases to calculate

*** not calculated for this model

**Table 8.2 Percent Change in the Relative Effects of the Semi-Standardized Hazard Coefficients on Neonatal Mortality: United States, 2000-2005**

| | Semi-Standardized Hazard, Percent Change | | |
|---|---|---|---|
| **Variable** | **Twins** | **Triplets** | **Twins & Triplets** |
| Plurality | *** | *** | -3.3* |
| Very Low Birthweight | 79.9* | 46.0 | 79.3* |
| Low Birthweight | 15.5* | -20.6 | 13.2* |
| Over Birthweight | 4.3 | ** | -4.1 |
| Gestational Age | 174.6* | 360.7* | -65.3* |
| Hispanic | .487 | 5.8 | 1.0 |
| Non-Hispanic Black | -8.5* | 6.8 | -7.9* |
| Age of Mother | 11.6* | -11.1 | -10.9* |
| Parity | 5* | 7.3 | 65.9* |
| Male | 12.6* | 9.9 | 12.5* |
| Firstborn | .1 | 7.9 | .4 |

* significant at .05 level

** too few cases too calculate

*** not calculated for this model

**Table 8.3 Percent Change in the Relative Effects of the Semi-Standardized Hazard Coefficients on Postneonatal Mortality: United States, 2000-2005**

| | Semi-Standardized Hazard, Percent Change | | |
|---|---|---|---|
| **Variable** | **Twins** | **Triplets** | **Twins & Triplets** |
| Plurality | *** | *** | -6.0* |
| Very Low Birthweight | 55.1* | 50.1 | 58.2* |
| Low Birthweight | 24.1* | -27.4 | 23.3* |
| Over Birthweight | 6.2* | ** | 6.2* |
| Gestational Age | -32.8 | -36.8* | 49.8* |
| Hispanic | 4.3* | -6.2 | -11.1 |
| Non-Hispanic Black | 13.1* | 28.9* | 13.9* |
| Age of Mother | 31.2* | 9 | -29.3* |
| Parity | 27.7* | 9.1 | 26.8* |
| Male | 10.3* | 2.4 | 10.0* |
| Firstborn | 4.8 | 6.1 | 4.9 |

* significant at .05 level

** too few cases too calculate

*** not calculated for this model

**Table 8.4 Percent Change in the Relative Effects of the Semi-Standardized Hazard Coefficients on Infant Mortality: United States, 2000-2005**

| | Semi-Standardized Hazard, Percent Change | | |
|---|---|---|---|
| **Variable** | **Twins** | **Triplets** | **Twins & Triplets** |
| Plurality | *** | *** | -4.5* |
| Very Low Birthweight | 64.6* | 25.7 | 64.6* |
| Low Birthweight | 15.4* | -31.1 | 13.3* |
| Over Birthweight | 5.9* | ** | 5.9* |
| Gestational Age | -77.1* | -72.3* | -56.9* |
| Hispanic | -1 | 3.7 | -0.7 |
| Non-Hispanic Black | -1.3 | 13.0* | 0.3 |
| Age of Mother | -18.8* | -10.6 | -18.2* |
| Parity | 13.1* | 8.5 | 13.2* |
| Male | 11.8- | 8.2 | 11.6* |
| Firstborn | 2 | 6.9 | 2.2 |

* significant at .05 level

** too few cases too calculate

*** not calculated for this model

# VITA

**Bethany Suzanne DeSalvo**
Department of Sociology
c/o Dr. Dudley Poston
Texas A&M University
College Station, Tx 77843-4351

**Education**
2010 Ph.D. in Sociology, Texas A&M University
2004 M.A. in Student Affairs in Higher Education, Indiana University of Pennsylvania
2002 B.A. in Cultural Communication, University of Pittsburgh

**Research Interests**
Mortality; Fertility; Demography of Asian Populations; Population Aging; Demography; Medical Sociology

**Publications**
Poston, D.L.., B. DeSalvo, and H Kincannon. 2009. "Sex and Sex Structure." in Zeng Yi (ed.), *The Encyclopedia of Life Support Systems, Volume 5: Demography*. Pp 6-94. New York: United Nations, UNESCO.

Poston, D.L., B. DeSalvo, and L. Meyer. 2009. "Malthusian Theory of Population Growth.") I Clifton D. Bryant and Dennis L. Peck (eds.), *Encyclopedia of Death and the Human Experience.* Pp. 684-687 Thousand Oaks, CA: Sage Publications, Inc.

Poston, D.L., B. DeSalvo, and R. Cortes. 2009. "Neonatal Deaths." in Clifton D. Bryant and Dennis L. Peck (eds.), *Encyclopedia of Death and the Human Experience.* Pp. 781-783. Thousand Oaks, CA: Sage Publications, Inc. Pp. 781-783

Poston, D.L., H. Kincannon, and B. DeSalvo. 2009. "Sex Ratio." In Harry Reis and Susan Sprecher (editors), *Encyclopedia of Human Relationships*. Newbury Park, CA: Sage Publishers.