UNIVERSITY OF GHANA

STATISTICAL ANALYSIS OF FACTORS AFFECTING MATERNAL MORTALITY IN GHANA

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL STATISTICS DEGREE.

October 25, 2018

DECLARATION

I hereby declare that this submission is my own work towards the award of the MPhil. degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which had been accepted for the award of any other degree of the university, except where due acknowledgment had been made in the text.

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DEDICATION

To Mr. Edwin Koranteng Acquah (of blessed memory), Akompi Janet, Nana Osafo Acquah (PhD), Auntie Joyce Bassa and Mr. Bassa Raphael for their unwavering love and prayers. May God richly bless them!

ACKNOWLEDGMENT

I first of all convey my heartfelt gratitude to the Almighty God for his divine providence. I am thankful to all the Lecturers at the Statistics Department, especially my indefatigable Supervisors, Dr. Louis Asiedu and Dr. Anani Lotsi, for their unflinching guidance.

My appreciation goes to the Assistant Vice Principal (Lower Secondary) of Ghana International School, Mrs. Angela Van Der Puije, for her candid concerns about maternal mortality. The depth of her sincere desire to see the end of maternal mortality convinced me to undertake a study to that effect.

Further, may I say a big thank you to all my family and friends, especially Mr. and Mrs. Dei-Oppong, Frederick Danso, Doris Korantemaa, Shandorf Koranteng, Gerald Frimpong, Osman Iddrisu and Samuel Aviah for their prayers.

Above all, I extend my heartfelt appreciation to Prof. Henry De-Graft Acquah (UCC), Dr. Francis Nsiah (UCC) and Mr. Francis Frimpong (Minerals Commission) for the recommendations, and finally, a big thank-you to the Assistant Vice Principal (Upper Secondary) of Ghana International School, Mr. Francis Hukpati, for encouraging me to pursue a master's degree programme. He never stopped saying, " my friend, do your masters now."

ABSTRACT

This study evaluated the relationship between possible medical and social factors affecting maternal deaths. A conceptual framework was developed to help identify, classify, model and resolve these factors (by implementing the recommendations). A generalized linear model was fixed using the 'R' statistical analysis software. Three data sets (2016 and 2013 data sets on maternal mortality, and a data set on the causes of maternal deaths) were used in the analysis, which showed wide regional variations in maternal mortality ratios and maternal mortality rates. For the data set on causes of maternal deaths, Hypertensive disorder was the leading determining factor of maternal deaths, followed by Hemorrhage. Eastern Region was leading in Maternal Mortality Ratio (461 maternal deaths per 100000 live births) in 2016, followed by the Volta region with Maternal Mortality Ratio (MMR) of approximately 445 per 100000 live births. The Upper West Region had the least MMR (179 per 100000 live births) in 2016. Antenatal care and Postnatal care attendance have been found to be significant contributing factors of maternal mortality. Conclusively, the Eastern Region showed the highest risk of death per woman in 2016. The National Maternal Mortality Ratio for 2016 was approximately 306 per 100000 live births, which was an improvement on 2013 MMR, approximately 379 maternal deaths per 100000 live births. It is therefore recommended that particular attention be given to Antenatal care and Postnatal care in the quest to attain the Sustainable Development Goal target of 70 maternal deaths per 100000 live births by 2030.

CONTENTS

LIST OF ABBREVIATION

AA ..... Antenatal Attendance

AR ..... Ashanti Region

BAR ..... Brong Ahafo Region

CR ..... Central Region

DHMIS ..... District Health Management Information System

EmOC ..... Emergency Obstetric care

ER ..... Eastern Region

GAR ..... Greater Accra Region

HIV ..... Human Immuno-Difficieny Virus

KBTH ..... Korlebu Teaching Hospital

LRT ..... Likelihood Ratio Test

MDG ..... Millennium Development Goals

MMR ..... Maternal Mortality Ratio

MMRate ..... Maternal Mortality Rate

MMRFMS ..... Maternal Mortality Risk factor Management System

NR ..... Northern Region

NSAH ..... Number of Surrounding villages Assessing Health Care

PA ..... Postnatal Attendance

SHP ..... Skilled Health Personnel

UER ..... Upper East Region

UNDP ..... United Nations Development Project

UNICEF ..... United Nations International Children's Emergency Fund

UWR ..... Upper West Region

WHO-ICD World Health Organization-International classification of Diseases

WIFA ..... Women In Fertility Age

WR ..... Western Region

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This study seeks out to measure the relation between possible medical and social factors affecting maternal deaths and to create interval estimates of the risk linked to these factors. An outline of a conceptual framework for risk factor management will be provided and a risk-factor classification be developed for modeling. This chapter presents the study background, the problem statement, questions that guided the study, objectives, research methodology, the delimitations, and justifies why the study is necessary.

1.2 Background

From the mid-19th century, maternal death was high in the western part of the world. A consistent record keeping of maternal deaths was therefore started in the mid-1930s. The rate of maternal deaths was on a high level, despite the fact that there was considerable differences between countries in the altitude of this level. This trend however began to decline from 1937, and for about 20years, the differences between countries had almost vanished (Irvine, 2000).

Globally, the issue of maternal mortality was brought to light when Rosenfield and Maine in 1985 circulated a stimulating editorial in the Lancet, in which they disclosed that many underdeveloped nations were ignoring this significant problem and that available measures would doubtfully decrease the high rates of maternal deaths in these parts of the world. Harrison's (1985) report on maternal mortality during childbirth was also key in bringing to bare the dire

consequences of maternal mortality. He analyzed, consecutively, 22,774 births that occurred in hospitals in Northern Nigeria and Zaria, which highlighted the disheartening nature of deaths associated with child birth.

A publication by the World Health Organization (1986) on maternal deaths, "Helping women off the road to death," was another remarkable contribution to the campaigne against maternal mortality. This, together with other contributions informed the organization of the "safe motherhood" symposium in 1987 in Kenya's capital town, Nairobi. Presenters at the symposium gave global breakdown of statistics on pregnancy and child-birth related difficulties that resulted in deaths. According to the Speakers, the likelihood that a woman would die during childbirth, in Sub-Saharan Africa, was 1 out of 21 and that this was 400 times higher than that of the North American or Western Europe counterpart.

According to the Global Health Observatory's (GHO) report, in 2015 about 830 women lost their lives eachday due to pregnancy and childbirth-related issues. Approximately, all of these death cases happened in underdeveloped Nations, and majority of these deaths could have been avoided. The primary contributory factors of maternal deaths, to the GHO, were haemorrhage, hypertension, infections and indirect causes, that generally result from interaction between pre-existing medical condition and pregnancy. Out of the 830 maternal deaths that occurred daily, 550 happened in Sub-Saharan Africa and 180 in Southern Asia, as compared to 5 in developed countries. The danger of a woman losing her life in an underdeveloped country from a maternal-linked issue in her lifetime is about 33 times more compared to a woman living in a developed nation. Clearly Maternal death is a health gauge that indicates very extensive breaches between poor and rich, rural and urban areas, both within and between countries. From the GHO 2015 report, 99% of the women who die from complications related to childbirth and pregnancy reside in low- and middle-income countries.

There has been a considerable advancement in decreasing maternal deaths after the inception of the Millennium Development Goals (MDG). During 1990 and 2015 period, the proportion of women losing their lives from issues linked to childbirth and pregnancy has declined by 43% from a projected 532000 in 1990 to 303000 in 2015. The regular yearly reduction rate in maternal deaths has increased by two folds in the past decade (2005 to 2015), as compared to the previous decade(1990 to 2000). Most Nations within Sub-Saharan Africa have reduced by half levels of maternal deaths since 1990. Other jurisdictions, including Asia and North Africa, have made even greater progress. The maternal mortality ratio (MMR) in underdeveloped countries, as reported by past findings, is put at 240 deaths per $100,000$ live births against 16 deaths per $100,000$ live births in developed countries. In furtherance, the estimated worldwide lifetime risk of a maternal death, considerably, decreased from 1 out of 73, to 1 out of 180 (WHO, 2015).

The World Health Organization reports that about 80% of maternal deaths are instigated by infections, high blood pressure during pregnancy, severe bleeding and insecure abortion. Malaria, anaemia and AIDS during pregnancy are some other contributing factors of maternal deaths in underdeveloped countries.

1.2.1 Maternal mortality ratio trend in Ghana

Maternal mortality ratio (MMR) is defined as the death of a woman while pregnant or within 42 days of the end of pregnancy regardless of the length and location of the pregnancy (WHO-ICD 10). Ghana has experienced a considerable reduction in maternal deaths over the years. According to the United Nations Population Fund (UNPF, 2011), the MMR of Ghana was 319 in 2015 compared to MMR of 325 in 2010. Table 1.1 shows a statistical overview of Ghana's maternal mortality ratio from 1990 to 2015.

Table 1.1: Maternal Mortality Ratio of Ghana (1990-2015)

Year	MMR (MMR)[a]	Maternal deaths	Live births [b]
	per 100000 live births	Numbers	Thousands
1990	634 [436 – 911]	3600	572
1995	532 [378 – 746]	3200	606
2000	467 [342 – 645]	3100	654
2005	376 [282 – 506]	2700	727
2010	325 [237 – 437]	2700	820
2015	319 [216 – 458]	2800	884

a. MMR and PM are calculated for women 15-49 yrs.
b. Live birth data are from world population prospects; the 2015 Revision New York, Population Division, Department of Economics and social affairs, United Nations secretariat; 2015.

The above table shows that maternal mortality ratio has been reducing since 1990. However, the rate of decline wasn't sharp enough to ensure the achievement of the Millennium Development Goal Target 5A. Hence early identification of the factors accounting for this slow reduction trend is key in developing intervention strategies.

1.3 Profile of the study area

Figure 1.1: The Ghana map

Ghana is currently separated into ten regions and further partitioned into 216 local districts for governmental purposes. The smallest Region in terms of area, among the ten Regions, is the Greater Accra Region. However, it is the second most inhabited Region with a population of $4,010,054$, amounting to 15.4% of the country's total population. The Greater Accra Region has five districts; Tema Municipal Area, Accra Metropolitan Area, Ga West District, Ga East District and Dangme East District. Table 1.2 below provides a brief statistical overview of Ghana's population and land size for the ten Regions.

Table 1.2: Ghana's Population by Region

Region	Capital	Area(km^2)	Population(2010 census)
Ashanti	Kumasi	24,889	4,780,380
Brong Ahafo	Sunyani	39,557	2,310,983
Greater Accra	Accra	3,245	4,010,054
Central	Cape Coast	9,826	2,201,863
Eastern	Koforidua	19,323	2,633,154
Northern	Northern	70,384	2,479,461
Western	Secondi-Takoradi	23,921	2,376,021
Upper East	Bolgatanga	8,842	1,046,545
Upper West	Wa	18,476	702,110
Volta	Ho	20,570	2,118,252

1.4 The Problem Statement

The need to achieve a relatively low maternal mortality rate has long been recognized by the United Nations, which came up with the Millennium Development Goal target of a three quarter reduction in maternal mortality by 2015. Many developing countries, including Ghana, have not been able to achieve this goal by the set period. The World Health Organization has attributed the failure by some countries to achieve this target to growing situations of conflict and humanitarian settings, disaster and post-conflict (WHO, 2015). The country's Maternal Mortality ratio (MMR) reduced from 325 (Uncertainty Interval (UI); $237-437$) out of $100,000$ live births in 2010 to 319 (UI; $216-458$) out of 100,000 live births in 2015. This rate of decline (1.84%) is far below the rate needed to attain the Sustainable Development Goal (SDG) objective of a worldwide MMR below 70 per 100000 live births. On the average, 7.5% annual rate reduction is required to achieve the global MMR of 70 per $100,000$ live births by 2030. It is obvious that Ghana's current reduction rate in maternal mortality will not be able to realize this goal.

Thus, there is a need for a better understanding of the factors causing maternal mortality and a structured approach in identifying and modeling maternal mortality rate in order to ensure the realization of the sustainable Development Goal of at most 70 per $100,000$ live births by 2030.

1.5 Research questions

The following questions would guide the research study

1. What are the main factors related to maternal mortality?
2. How do we classify these factors for easier identification and modeling?
3. What are the current research developments in modeling these factors?

1.6 Research objectives

The broad objective of the research is to develop a maternal mortality risk factor management system - the process of identifying, classifying, modeling and resolving risk factors.

Specifically the study seeks to

- identify the key factors affecting maternal mortality in Ghana.
- outline a conceptual framework for risk factor management and to develop a risk factor classification for modeling.

The result of this study will be valuable to the Nation in managing risk factors related to maternal mortality.

1.7 Methodology

Generalized linear models (GLMs) would be employed to measure the relationship between possible medical and social factors affecting maternal deaths and to

create an interval estimates of the risk connected to these factors. GLMs uses Maximum Likelihood Estimation (MLE) to obtain the parameters, and therefore relies on large sample approximations.

1.8 Data Acquisition

Secondary data from the District Health Information Management System(DHIMS) in the ten regions of Ghana and Ministry of Health's 2016 survey report would be used for the analysis. These data were

- Yearly recorded maternal deaths
- Yearly recorded deliveries
- Number of surrounding villages accessing health care
- Antenatal care attendance
- Postnatal care attendance

1.9 Analytical tool

The R Data Analysis Softare would be used in analyzing the data to produce inference tools and model checking such as the Deviance, Residual analysis, Confidence intervals and Overdispersion. Other numerical and statistical simulation procedures of estimating parameters would be analyzed when considered prudent.

1.10 Source of Knowledge

Balm Library (University of Ghana), the District Health Information System Management records and the Ministry of health's research center were the key sources of information for the fruitful finish of this research work. Others include the internet and Obstetrics Professionals.

1.11 Justification

Ghana could not achieve the Millennium Development Goal (MDG) 5A objective of three quarter reduction of maternal deaths by 2015. In 2016, the Greater Accra Region recorded the highest number of maternal deaths (197), followed by the Northern Region with 133 maternal deaths(Ministry of Health [MOH], 2017). For Ghana to achieve the Sustainable Development Goal (SDG) objective of at most 70 per 100,000 live births by 2030, the current intervention strategies must be reviewed and some new recommendations be made.

This study would provide a conceptual framework outline for risk factor management and a risk factor classification for modeling. The results would be valuable to the Nation in managing risk factors associated with maternal mortality so as to reduce maternal deaths drastically.

1.12 Scope and Delimitation

This study would be restricted to regional-based records on maternal mortality. The seondary data obtained from District Health Information Systems were across 50 hospitals in the country. Special attention would be given to the data on ascription of cause of maternal death from the Korle-Bu Teaching Hospital, since it is the major referral hospital in Ghana. This hospital often treats cases that place pregnant women in high risk group for death. The data collection procedure also limits one's capacity to assign an exact cause of death.

1.13 Thesis Organization

This thesis is categorized into five chapters. The first one is the introductory chapter, which gives detailed background of maternal mortality, the problem statement, research questions, research objectives, a brief description of the methodology, delimitations of the research and the justification of the study.

Chapter two reviews past literature associated with maternal mortality with regards to the thesis objectives and chosen models. Expected outcome and other relative results of similar studies are also presented here. A theory of the Generalized Linear Model, formulations and methods of solution are presented in the third chapter. The data collection technique, analysis and results are discussed in the forth chapter. Chapter five summarizes and concludes the entire study with recommendations that are centred on the findings of the study.

CHAPTER 2

Literature Review

2.1 Preview

About 830 women die each day from complications that result from childbirth and preventable causes of pregnancy, despite the 44% reduction in rate of maternal deaths since 1990. This, according to the United Nations Population Fund, is approximately one woman for every two minutes and 20 or 30 women face severe or long-lasting complications (UNFPA, 2017). This chapter reviews literature related to maternal mortality. It also takes into accounts abstracts on literature in accordance with the model to be employed and the general working title.

2.2 Maternal mortality in general

Between 1990 and 2010, maternal deaths has declined globally by approximately 50%, and the regular yearly maternal death reduction rate has increased by more than two folds in the past decade. This, notwithstanding, maternal death remains high in underdeveloped nations, especially in the outskirt and less accessible areas. A mother's death compromises nutrition and general child care and these children mostly do not avail themselves of routine health care in order to enjoy some interventions such as vaccination. This consequence is even worse in disadvantaged communities (Susana et al., 2015).

In 2010, Hogan and Foreman measured the sensitivities and the patterns of maternal deaths for 181 countries in the article, " Maternal mortality for 181 countries, 1980-2008: a systematic analysis of progress towards Millennium

Development Goal 5." The Authors created 2651 record of observations of maternal deaths involving 181 countries for 1990 through 2008, using verbal autopsy studies, vital registration data, censuses, and surveys. The researchers employed vigorous investigative procedures to produce maternal death estimates and Maternal Mortality Ratio (MMR) throughout the study period (1980 to 2008). In furtherance, they verified the sensitivity of the data to model requirement and showed the out-of-sample explorative soundness of the procedures. They argue that there were 342,900 maternal deaths globally in 2008, a decline from 1980's 526, 300 maternal deaths. This resulted in a worldwide decrease in MMR from 422 in 1980 to 320 in 1990 and eventually, 251 out of 100,000 live births in 2008. They observed that, without HIV, 281,500 maternal deaths would be recorded globally in 2008. In concluding, the researchers intimated that only 23 countries were on path to realizing the Millennium Development Goal objective of 75% decrease in maternal deaths by the year 2015, and that these nations, China, Egypt, Ecuador and Bolivia had been attaining enhanced headway.

In their bid to apprise past maternal and child death estimates using an improved data and more vigorous procedures to provide the best available proof for following progress on Millennium Development Goals (MDG) 4 and 5,the Authors tried a large set of substitute models for maternal deaths. They used a collective method based on the model with the best out-of-sample analytical validity to produce new estimates from 1990 to 2011. The authors observed a reduction in maternal death from 409,100 (uncertainty interval 382,900-437,900) in 1990 to 273,500 (UI: 256,300-291,700) deaths in 2011. They observed further that there were 56, 100 HIV-related maternal deaths during pregnancy in 2011, and that trends in underdeveloped countries suggest that 31 countries would achieve MDG 4, 13 countries MDG 5 and 9 countries could attain both (Rafael et al., 2011).

A research was conducted in four States of Northern Nigeria to project maternal mortality level using the 'Sisterhood method.' In all, 3,080 participants reported 7,731 maternal sisters of which 593 were reported dead and 298 of those dead were maternal-related. To the Authors, this matched to a lifetime danger of maternal death of 9% and maternal mortality ratio (MMR) of 1271 maternal deaths out of 100000 live births. The Authors further argue that the "Sisterhood method" for estimating MMR, in situations where the sample size is very large, is the perfect approach in such settings because it requires fewer participants than vital registration and cohort studies. However, they agree that projections from this method should be considered as orders of magnitude instead of specific ratios since they can have varied confidence intervals, and that projections from this technique are fairly exact and the degrees of accuracy may be low as a result of the retroactive form of the data and absence of proof of the information given. The four States considered for the study were selected based on the fact that they had generally poor maternal and child health pointers. Henry and co. reported that antenatal care services were present in some selected health care facilities in the four States and that per the Nigerian Demographic and Health Survey of 2008 in Northern Region,59.1% of expectant mothers in the five years before the survey had no antenatal care, and of those enjoying antenatal service, only 37% enjoyed these services from a trained health care provider (Henry, Sally, Findley, & Godwin, 2012).

A study conducted by the Ghana Statistical Service suggests that 12 percent of all pregnancies that happened within the ten years preceding the research failed to result in a live birth. Again, the research stated that approximately one out of every four pregnancies to women between the ages of 15 and 19, was lost early through induced or spontaneous abortion. The study further reported that early miscarriages were particularly high among women of these ages and that two

out of five pregnancies to women in this age group resulting in early miscarriage (Ghana Statistical Service and Macro International, 1998).

In their quest to examine the quality of data used to estimate Maternal Mortality Ratio (MMR), Yoko and co. conducted a study titled, "Make it happen 2015: validation of the maternal mortality ratio in Trinidad and Tobago from 2000-06". A retrospective reproductive age mortality survey (RAMOS) was used during 2000-2006 in measuring nationwide estimates. The researchers realized that, data from Trinidad and Tobago Central Statistical Office (CSO) and external sources of data produce incompatible outcomes. The CSO's MMR estimate for 2005 was 34.8, whereas the World Bank and UNICEF recorded, respectively, 55.0 and 45.0. The authors commended some maternal death review instrument across all health jurisdiction in Trinidad and Tobago (Yoko & Vincent, 2011).

In a research titled,"Towards elimination of maternal deaths: maternal deaths surveillance and response" the Researchers argue that the current method for estimating maternal deaths lacks accuracy and are not appropriate for checking progress in the short term. The Authors further intimated that National maternal mortality ratios (MMRs) alone hardly give important information on where major problems of mortality is found, the causes, the people concerned, and above all, what sub-national variations occur. According to them, the vision "no mother should lose her life when giving birth" shows the human rights view on maternal deaths and would require at least 90% of maternal deaths be prevented so as to make maternal deaths a probable target for an elimination plan. Hounton and co. report further that absence of vital registration in underdeveloped countries and the difficulties in the determination of the status of pregnancy, especially in its early stages, hinder the tracking progress on maternal death rates. They therefore recommended that maternal deaths public health surveillance is established to monitor maternal mortality (Hounton et al.,

2013).

The primary contributory factors of maternal deaths for women of all ages are obstetric related; hemorrhage as the major global contributing factor of maternal death (27%), followed by hypertensive disorders (4%) and Sepsis having 10%. Other factors include abortion (8%) and embolism (3%). Some Authors further observed significant regional differences for the percentage each factor contributes to total maternal deaths (Neal et al., 2016).

Maternal death is defined by the World Health Organization as "the death of a woman while pregnant or within 42 days of termination of pregnancy, regardless of the length and location of the pregnancy, from any cause linked to or worsened by the pregnancy or its management but not from accidental or incidental causes". Meanwhile, maternal mortality ratio (MMR) is defined as the ratio of the number of maternal deaths for a given time interval out of 100,000 live births within the same time-period.

Thus,

$$\text{Maternal Mortality Ratio(MMR)} = \frac{\text{Maternal Deaths}}{\text{Total Livebirths}} \times 100000\text{livebirths}$$

From a study conducted at the Komfo Anokye Teaching Hospital(KATH) in Kumasi, Ghana, Lee (2010) of the University of Leicester found that between January 2008 and May 2010, the hospital recorded maternal mortality ratio of 1021.9 out of 100,000 livebirths (95% confidence interval; 906.6-1130.8). In a similar research conducted at the Tamale Teaching hospital,Ghana, Guamanga et al. (2010) reported a maternal mortality ratio of 493 out of 100,000 livebirths. These results are in line with past research findings that greatest percentage of maternal deaths happen in health care facilities where

fundermental circumstances that frequently lead to death are mostly taken care of.

Despite the free maternal care intervention strategy introduced by the government of Ghana, maternal deaths situations in the country remain unstable. Aikins's (2010) thesis, "Female Health and Development, A case study on maternal health scheme in Ghana", sought to find out whether the free antenatal and delivery care provided by the government of Ghana had increased pregnant women hospital attendance and also, whether this has led to a decrease in maternal mortality. The participants were three health workers and fifty-five expectant mothers. The main tools employed in data collection were semi-structured interviews and observations. Results from the research indicate that availability of trained health attendants at delivery as per expectant mothers ratio was rather poor. She put Doctor to pregnant women ratio at one is to seventeen thousand seven hundred and thirty-three (17,733) and that of a Nurse to patients ratio at one is to one thousand five hundred and ten (1,510) with differences across urban and rural settings.

2.3 The Medical Explanatory Model

A number of studies have proven the following as the most frequent clinical factors of maternal deaths and lasting morbidity during pregnancy and delivery.

2.3.1 Postpartum Hemorrhage (PPH)

PPH is currently reported as the principal cause of maternal death. For instance, in the United States, PPH account for approximately 11.4% of maternal deaths. In developing countries such as Ghana, lack of experienced caregivers who might be able to effectively handle PPH if it occurs, and lack of blood transfusion

services have been cited as major contributions of unfavorable outcomes of PPH. Postpartum Hemorrhage is simply explained as blood loss of more than 500ml following vaginal delivery or more than 1000ml following Cesarean delivery. If these blood loss occurs within 24hours of delivery, it is called primary PPH, otherwise, secondary PPH.

Out of 634 pregnancy-related deaths that happened between 2004 and 2008 at Korle-Bu Teaching Hospital, 21.8% was as a result of Postpartum Hemorrhage (Der et al., 2013).

2.3.2 Hypertensive disorders

This is one of the obstetric emergencies that are difficult to prevent or manage. It is a major factor of maternal death in Africa. In a retroactive descriptive study conducted at the Korle-Bu Teaching Hospital (KBTH) in Accra, the Authors reported that 63 out of 199 maternal deaths that happened between 2010-2011 were attributable to hypertensive disorders (Adu-Bonsaffoh, Oppong, Binlinia & Obed, 2013). Hypertensive disorders normally progresses to eclampsia characterized by severe renal failure, intracerebral hemorrhage, pulmonary edema and death.

2.3.3 Anemia

According to the Ghana Demographic Health survey, the number of pregnant women with anemia climbed from 65 percent in 2003 to 70 percent in 2008. The report further stated that at least 9000 expectant mothers in Ghana would lose their lives by 2020 if the high levels of anemia among pregnant women were not put to check (Ghana Demographic Health Survey). Malaria is the principal cause of anemia in Ghana.

2.3.4 Sepsis

Unnoticed or poorly handled maternal infections can result in Sepsis, death or disability on the part of the mother and a corresponding greater possibility of premature neonatal infection and other adverse consequences (WHO, 2017). Sepsis normally occurs when the amniotic sac raptures way before delivery occurs, when the vaginal examinations are too common or when obstructed labour happens. Long term consequences of puerperal sepsis include pelvic inflammatory diseases, secondary infertility and in rare cases, maternal tetanus (Senah, 2003).

2.3.5 Obstructed Labour

This is mostly caused by cephalo-pelvic disproportion- a mismatch between the fetal head and the mother's pelvic brim. This therefore impairs the smooth passage of the baby. In severe cases, it could lead to fistulation, whereby urine and faecal matter have access to the reproductive system. The number of maternal deaths due to obstructed labour or labour dystocia varies between 4% and 70% of all maternal deaths, accounting to maternal mortality ratio of 410 per 100,000 livebirths (Neilson, Lavender, Quenby & Wray, 2003)

2.3.6 Abortion

In a study conducted in Benin, Ivory Coast and Senegal, "4116 women were admitted for obstetrical complications during the first trimester of pregnancy. 1525 (37%) were admitted for complications of induced abortion, 1834 (45%) for complications of spontaneous abortion, 651 (16%) for ectopic pregnancy and 106 (3%) for molar pregnancies. A total of 42 of these 4116 women died, 37 (88%) of these deaths resulted from complications of induced abortion" (New Englang Journal of Medicine[NEJM], 2002). This supports past studies findings that complications of induced abortion is the major contributory factor of death in the first trimester of pregnancy. According to the Ghana Demographic and Health

Survey (Ghana Statistical Service and Macro International, 1998) 12 percent of all pregnancies that happened before the study failed to result in a live birth. Moreover, the study stated that approximately one out of four pregnancies to women aged between 15 and 19 years was lost early due to spontaneous or induced abortion. It was observed further that early miscarriages were particularly high among women aged between 15 and 19 with about two out of five pregnancies to women in this age group resulting in early miscarriage. Abortion is usually characterized by severe bleeding, lower abdominal pains, and passage of foetal and placental tissue.

2.3.7 Others

Other medical factors that contribute to maternal death include HIV and Cardiac disorders.

2.4 The Socio-Cultural Context

Some cultural practices in Ghana contribute immensely to maternal mortality. Key among them is Betrothing. In the Northeern part of Ghana, girls are betrothed as early as seven years. These girls are compelled to move into their potential husbands homes in their early teen ages. Because these children don't have well developed pelvic to contain pregnancies, most of them die during labour, especially when there is no timely medical intervention. Another contributing factor is taboos. In some Ghanaian societies, pregnant women are prohibited from taking certain foods, with the believe that such foods would negatively affect their babies. Darko (1992) observed that, among the Akwapims, expectant mothers were not allowed to buy tomatoes, pepper, okro, and garden eggs from the market. It is believed that pregnant women who voilate this order would have their children infected with acute rashes and eventually suffer some degree of disability. This practice could obviously lead to malnutrition, thereby affecting

the growth and the development of the baby, as well as the health conditions of the expectant mother.

2.5 Role of Antenatal and Postnatal care in Maternal Mortality

Antenatal and Postnatal care are factors that contribute greatly to maternal mortality. Unfortunately little attention is attached to them in developing countries such as Ghana. A study conducted at N. Wadia Maternity Hospital in India between 1929 and 1988 showed a decline in Maternal Mortality Ratio (MMR) from 1920 during 1929-1939 period to 82 per 100000 live births in 1980-1988. According to the Researchers this progress in reduction of maternal death over decades was due to several factors such as an effective postnatal, intranatal and antenatal service. It was observed further that direct obstetric death also reduced from 670 to 41 per 100000 live births. These figures, according to researchers, indicate utilization when health care facilities are free of charge and available within the shortest possible distance from one's residence(Pandit, 1992).

A similar research titled " importance of Antenatal care in reduction of maternal morbidity and mortality," was conducted in Pakistan, a developing country with a population of over 140 million and a high maternal mortality ratio of 340 per 100000 live births in 2002. The major causes of maternal mortality in Pakistan, like other developing countries remain hemorrhage(21%), eclampsia(18.6%), Sepsis(13.3%), abortion(11%), obstructed labour(8.7%) and others(27.4%). The researchers argue that effective antenatal service, its delivery and accessibility can generally prevent all the above factors that need urgent obstetrical care. They argue further that antenatal attendance play a key role in creating confidence among the stake holders. In furtherance, they observed that in underdeveloped countries only 65% women enjoy antenatal service as compared

to 97% in developed countries (Inam & Khan, 2002).

2.6 Number of Surrounding Villages Assessing Health care

The number of surrounding villages accessing health care from a facility indicates the level of pressure on the facility. This affects quality urgent obstetric service, which is key to survival in times of complications. According to McCaw-Binns et al., distance and delay in treatment are the principal determinants of maternal deaths. They argue that time away from the family and long distances greatly affect women readiness to seek health care (McCaw-Binns, Ashley, Walker, Standard-Goldson & MacGillivray, 2001).

Obviously antenatal care, postnatal care and number of villages accessing health care play roles in maternal mortality. It is for this reason that they were considered as explanatory variables, for the first time in Ghana, using the Generalized Limear model.

2.7 Use of Generalized Linear Model in Maternal Mortality

In a research conducted at Bangledesh, Saifuddin Ahmed and Kenneth Hill (2010) employed the generalized linear models in analyzing the research data. The data was based on deaths that happened over a three year period. They reported that the maternal mortality ratio in Bangledesh declined from 574 to 382 deaths per 100000 live births during 1990-2000, even though the percentage of deliveries by trained birth attendants increased slightly over the period. According to the researchers, this rate of reduction was an indication that

Bangledesh was likely going to attain the MDG target of a three quarter reduction by 2015. The MMR for Bangledesh was 176 in 2015, which was a true reflection of the researchers prediction.

The Generalized Linear Models (GLMs) was used to develop point and interval estimates of risk connected to factors affecting maternal mortality. The authors recorded 402 maternal deaths per 262887 live births during the study period. This resulted in a MMR of 153 deaths per 100000 live births. Having measured maternal mortality ratios by site, they found MMR that ranged from 72 in Argentina to 321 in Pakistan. Hemorrhage and hypertensive disorders were identified as treatable factors that were the most highly linked to maternal deaths. In addition, they identified an increased risk of deaths among women whose deliveries were attended by a physician and those who had a cesarean section. After the 5 year study period, they observed an increase in the proportion of deliveries that were attended by a physician and delivery by cesarean, but they couldn't establish whether change in either of the two factors alone describes the decline in MMR. Per their findings, other factors that contributed to maternal death include seizures, anemia, obstructed labor and fetal malposition (Bauserman et al., 2015).

Due to cultural dynamics and difference in birth outcomes, their research findings could not be generalized to cover Ghana's maternal mortality situation. It is therefore prudent that a study is conducted in Ghana to find out factors that are impairing Ghana's progress towards the attainment of the Sustainable Development Goal target of 70 deaths per 100000 live births by 2030. It is the objective of this study to develop a conceptual framework outline for maternal mortality risk factor management.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Maternal death is measured using maternal mortality rate (MMrate), Maternal mortality ratio (MMR), lifetime risk of maternal death and proportion of maternal deaths among women of reproductive years (PM). Approaches commonly adopted to determining maternal deaths includes civil registration system, household surveys with direct death inquiry, indirect and direct sisterhood methods and reproductive age mortality studies (Saifudin & Kenneth, 2010). The chapter presents the models employed in the analysis, formulations and procedures for evaluating the data available to meet the research objectives.

3.2 Data Source and type

This research seeks out to measure possiblel medical and social factors affecting maternal deaths and to create interval estimates linked to these factors. The analysis is based on secondary data obtained from the District Health Management Information System (DHMIS) in the ten Regions of Ghana. The data is broken down by Antenatal care, Postnatal care, and Number of surrounding villages accessing health care. These data were yearly recorded maternal deaths and yearly recorded deliveries.

3.3 The concept of the Generalized Linear Models

"Generalized Linear Models (GLMs) is a class of models promoted by McCullagh and Nelder in 1982. It is an extension of multiple linear regression, which is an extension of the standard linear model. Under the GLMs, the response vector, Y, is considered to follow an exponential family distribution with mean U_i as a function of the linear predictor $\eta = \sum_{k=1}^{p} X_k B_k$. The GLMs has three basic components;

3.3.1 The random component

This explains the probability distribution of the response vector, $\mathbf{Y}$. For instance, binomial distribution for $\mathbf{Y}$ in the binary logistic regression, or normal distribution for $\mathbf{Y}$ in linear regression.

3.3.2 The systematic component

This identifies the explanatory variable in the model, specifically their linear combination in relating the so-called linear predictor, η, to a set of k control variables, $x_1, x_2, ..., x_k$, where $\mathbf{X} = (x_1, x_2, ..., x_k)$'. For example $B_0 + B_1X_1 + B_2X_2$ as in linear regression.

3.3.3 The link function

This specifies the relation between random and systematic components. It relates $\eta(x)$ to the expected value of the response vector. For instance, $\eta(x) = logit(\pi)$ for logistic regression, where π is the probability of success. Thus, a transformation of the mean response, $g[U(x)]$, is represented as a linear model in terms of $x_1, x_2, ..., x_k$. The most commonly used link functions are;

1. The logit function; $\eta(x) = log[\frac{U(x)}{1-U(x)}]$

2. The probit function; $\eta(x) = F^{-1}[U(x)]$

   where $F^{-1}(.)$ is the inverse of the cumulative distribution function of the standard normal distribution.

3. The logarithmic function; $\eta(x) = log[U(x)]$.

4. The inverse polynomial function; $\eta(x) = \frac{1}{U(x)}$

The density function of the response vector, $\mathbf{Y}$, under Generalized linear models can generally be written in the form,

$$f(\mathbf{y}, \theta, \phi) = exp\left[\frac{\theta x - b(\theta)}{a(\phi)} + c(\mathbf{y}, \Phi)\right] \tag{3.1}$$

Where $a(\phi), b(\theta)$ and $c(\mathbf{y}, \Phi)$ are known functions. θ is the canonical parameter, which is a function of the mean, U, of the distribution. ϕ is a dispersion parameter" (Khuri, 2009; p475-477).

Generalized linear models include:

- "Binary logistic regression which models how binary response variable, Y, depends on a set of q explanatory variables $\mathbf{X} = (x_1, x_2, ..., x_q)$" (Khuri, 2009, p.476). Given the probability of success, π, the probability mass function is given as

$$f(\mathbf{x}, \pi) = \pi^x(1-\pi)^{1-x}, x = 0, 1 \tag{3.2}$$

  and the corresponding link function is

$$g(u) = log(\tfrac{\pi}{1-\pi})$$

- The Normal Distribution;

$$f(\mathbf{x}, \mu, \sigma^2) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\left[-\frac{(x-\mu)^2}{2\sigma^2}\right]} \tag{3.3}$$

Where $-\infty < x < \infty, -\infty < \mu < \infty, \sigma \geq 0$

- Log-linear Model, which models the expected cell counts as a function of levels of categorical variables. For example, for a two-way table, the model is

$$log(\mu_{ij}) = \lambda + \lambda_i^A + \lambda_j^B + \lambda_{ij}^{AB} \tag{3.4}$$

where $\mu_{ij} = \epsilon(\eta_{ij})$ are expected cell counts. A and B represent two categorical variables, and $\lambda'_{ij}s$ are model parameters.

- The Poisson Distribution; a "discrete distribution whose random variable, X, takes the values $0, 1, 2, ...$ and has the probability mass function

$$f(\mathbf{x}; \lambda) = \frac{e^{(-\lambda)}\lambda^x}{x!}, x = 0, 1, 2, ... \tag{3.5}$$

where λ is the mean of X. The corresponding canonical link function is $g(\mu) = log\lambda$"

(Khuri, 2009; p475-477)

3.3.4 Estimating the parameters

The method of maximum likelihood estimation (MLE) is used to estimate the parameters of generalized linear models.

Assuming there are 'n' independent variables $y_1, y_2, ..., y_n$, each of which follows the exponential family distribution, such that the mean of Y_i is μ_i. Let $\eta_i = g(\mu_i)$, "where g is an appropriate link function such that

$\eta_i = \eta(x_i) = f'(x_i)\beta$, x_i is the value of x at which $\mathbf{Y} = y_i$ where i = 1,2,...,n.

The parameters are obtained as follows;

- Obtain the likelihood

$$L(\mu_1, ..., \mu_n, \mathbf{Y}) = f(y_1).f(y_2)...f(y_n)$$

- Find the log-likelihood

$$InL(\mu_1, ..., \mu_n, \mathbf{Y}) = In\left(f(y_1).f(y_2)...f(y_n)\right)$$

Now, since the linear predictor, η, depends on the parameters, say $\alpha_i, i = 1, 2, ..., n$ and the mean response is a function of η, the means $\mu_1, \mu_2, ..., \mu_n$ are therefore functions of the parameters. The Log-likelihood then becomes

$$InL(\alpha_1, \alpha_2, ..., \alpha_n, \mathbf{Y}) = l(\alpha_1, \alpha_2, ..., \alpha_n, \mathbf{Y})$$

- Differentiate, set the derivatives equal to zero and solve simultaneously the normal equations for the values of the parameters

$$\frac{\partial l(\alpha_1, \alpha_2, ..., \alpha_n, \mathbf{Y})}{\partial \alpha_1} = 0$$

$$\frac{\partial l(\alpha_1, \alpha_2, ..., \alpha_n, \mathbf{Y})}{\partial \alpha_2} = 0$$

$$\vdots$$

$$\frac{\partial l(\alpha_1, \alpha_2, ..., \alpha_n, \mathbf{Y})}{\partial \alpha_n} = 0$$

For instance, given that $\mathbf{Y}$ is a Poisson random variable, whose mean depends on the predictor variable $\mathbf{X}$, the expectation and the variance are respectively", $E(\mathbf{Y}|x) = \lambda(x)$ and $V(\mathbf{Y}|x) = \lambda(x)$

The link function,

$$g(\lambda) = log(\lambda)$$

satisfies the equation

$$g(\lambda(x)) = \beta_0 + \beta_1 x$$

Given the data, $x_1, x_2, ..., x_p$ and $n_1, n_2, ..., n_p$

The corresponding likelihood is given as

$$L(\beta_0, \beta_1; \mathbf{x}) = \prod_{i=1}^{p} \left[\frac{e^{-\lambda(x_i)} (\lambda(x_i))^{n_i}}{n_i!} \right] \tag{3.6}$$

and the loglikelihood is

$$logL = -\sum \lambda(x_i) + \sum n_i log(\lambda(x_i)) - \sum log(n_i!)$$

suppose the $x's$ take on the values 0 and 1 only

Then $\lambda(0) = \exp^{\beta_0}$ and $\lambda(1) = \exp^{\beta_0+\beta_1}$

hence,

$$logL = -\sum \exp^{\beta_0} I_{x_i=0} - \sum \exp \beta_0 + \beta_1 I_{x_i=1} + \sum n_i \beta_0 I_{x_i=0} + \sum n_i (\beta_0+\beta_1) I_{x_i=1} - \sum log n_i!$$

Now differentiating with respect to β_0 and β_1, equating to zero, and solving gives the maximum likelihood estimators

$$\hat{\beta}_0 = log \left(\frac{\sum n_i I_{x_i=0}}{p_0} \right) \tag{3.7}$$

where p_0 equals to the number of $0's$ among the $x's$ and

$$\hat{\beta}_1 = log \left(\frac{\sum n_i I_{x_i=1}}{p_1} \right) - \hat{\beta}_0 \tag{3.8}$$

where p_1 equals to the number of $1's$ among the $x's$

(Khuri, 2009; p479)

3.4 Negative Binomial

The Negative Binomial model is normally used for handling over-dispersion(when the variance is larger than the mean) in count data. Negative binomial regression model is obtained by attaching a multiplicative *random effect* θ, which represents unobserved heterogeneity, to a Poisson regression model. The mean θ_i is assumed to be constant or homogeneous under the Poisson. However, heterogeneity is introduced by specifying a distribution for θ_i. If θ_i follows Gamma's distribution with mean, $E(\theta_i) = \mu_i$ and variance, $Var(\theta_i) = \mu_i^2\nu_i^{-1}$, and $Y_i|\theta_i$ is a Poisson with conditional mean $E(Y_i|\theta_i) = \theta_i$, the marginal distribution of Y_i follows a Negative Binomial distribution;

$$P_r(Y_i = y_i) = \int P_r(Y_i = y_i|\theta_i)f(\theta_i)d\theta_i = \frac{\Gamma(y_i + \nu_i)}{\Gamma(y_i + 1)\Gamma(\nu_i)}\left[\frac{\nu_i}{\nu_i + \mu_i}\right]^{\nu_1}\left[\frac{\mu_i}{\nu_i + \mu_i}\right]^{y_1} \tag{3.9}$$

Now for a multiplicative fitted value, the mean is given as

$$E(Y_i|x_i) = \mu_i = e_i exp\left(x_i^T\beta\right) \tag{3.10}$$

and the likelihood for Negative Binomial regression model can be written as

$$l(\beta, a, \mathbf{Y}) = \sum_i \left(\sum_{r=1}^{y_1-1} log(1 + ar)\right) - y_i log(a) - log(y_i!) + y_i log(a\mu_i) - (y_i + a^{-1})log(1 + a\mu_i) \tag{3.11}$$

Hence the maximum likelihood estimates, $(\hat{\beta}, \hat{a})$ can be obtained by maximizing $l(\beta, a)$ with respect to β and a (dispersion parameter).

Thus,

$$\frac{\partial l(\beta,a)}{\partial \beta_j} = \sum_i \left[\frac{(y_i-\mu_i)x_{1j}}{(1+a\mu_i)}\right] = \sum_i \left[\frac{(y_i - e_i exp\left(x_i^T\beta\right))x_{1j}}{(1+ae_i exp\left(x_i^T\beta\right))}\right] = 0, j = 1,2,...,p \tag{3.12}$$

and

$$\frac{\partial l(\beta,a)}{\partial a} = \sum_i \left[\sum_{r=1}^{y_1-1}\left(\frac{r}{1+ar}\right)\right] + a^{-2}log(1+ae_i exp\left(x_i^T\beta\right)) - \left[\frac{(y_i+a^{-1})e_i exp\left(x_i^T\beta\right)}{(1+ae_i exp\left(x_i^T\beta\right))}\right] = 0 \tag{3.13}$$

(Noriszura & Jemain, 2007)

3.5 Goodness of fit test (Model checking)

The "Deviance and the Pearson's Chi-square statistic measures are used to assess how well the observed data match to the fitted model (in this case, GLMs). The goodness of fit test relates the observed values to the expected (predicted values). Usually, the observed data represents the fit of the saturated model- a model with as many parameters as there are points in the corresponding response surface design" (Khuri, 2009, p.487). Thus, the alternative hypothesis (H_A) represents the saturated model, M_A, since each observation has a separate parameter.

We use the goodness-of-fit to test the hypothesis

H_o: the model M_o fits

Versus

H_A: the model M_o does not fit

The Pearson goodness-of-fit statistic for a data vector $Y = (Y_1, Y_2, ..., Y_n)'$ is

$$\chi^2 = \sum_{j=1}^{n} \left[\frac{(Y_j - \hat{\mu_j})^2}{Var(Y_j)} \right] \tag{3.14}$$

where $Var(Y_j)$ is the variance function for the jth mean, and $\hat{\mu_j}$ is the maximum likelihood estimate of $\mu_j (j = 1, 2, ..., n)$

The Deviance statistic is given as

$$G^2 = 2 \sum_{j=1}^{k} X_j log \left(\frac{X_j}{n\hat{\pi}_j} \right) \tag{3.15}$$

Where X_j is the observed count in cell j, and $n\hat{\pi}_j$ is the expected count in cell j under the assumption that null hypothesis (H_o) is true.

"G^2 is sometimes called the likelihood-ratio test statistic, for comparing the likelihoods of two models. For instance, if $L_{max}(\theta, \mathbf{Y})$ represent the likelihood of the saturated model and $L(\theta, \hat{\beta})$ denote the likelihood function, maximized over $\hat{\beta}$, for a given generalized linear model with q parameters $(q < n)$, where $\hat{\beta}$ is the ML estimate of β. Then, given data vector, $\mathbf{Y}$, $L_{max}(\theta, \mathbf{Y}) > L(\theta, \hat{\beta})$. Thus, the likelihood ratio,

$$\Lambda = \frac{L(\theta, \hat{\beta})}{L_{max}(\theta, \mathbf{Y})} \tag{3.16}$$

provides a measure of goodness-of-fit for the given model. A small value of Λ (close to 0) indicates that the assumed model does not provide a good fit to the data" (Khuri, 2009; p488). For a large sample, a good measure of fit is given as

$$-2In\Lambda = 2 \left(InL_{max}(\theta, \mathbf{Y}) - InL(\theta, \hat{\beta}) \right) \tag{3.17}$$

Here, a large value of $-2In\Lambda$ indicates a bad fit.

Since the Poisson regression is used to analyze the data for this study, a deviance

expression for the Poisson distribution is detailed below.

Given the data vector, $\mathbf{X} = (X_1, X_2, ..., X_n)'$, where the $X_i's$ "are mutually independent and has the Poisson distributions with parameters $\lambda_i (i = 1, 2, ..., n)$, the log-likelihood is given as

$$l(\lambda_i; \mathbf{x}) = \sum_{i=1}^{n} [X_i log\lambda_i - \lambda_i - log(X_i!)] \tag{3.18}$$

and the corresponding deviance is equal to

$$-2In\Lambda = 2\sum_{i=1}^{n} \left[x_i In(\frac{x_i}{\hat{\lambda}_i}) - (x_i - \hat{\lambda}_i) \right] \tag{3.19}$$

Where $\hat{\lambda}_i$ is the maximum likelihood estimate for λ_i, and x_i is the realized value of X".

(Khuri, 2009; p479)

3.6 Residual Analysis

Residuals denote the part of the validation data not explained by the model. "They are used to assess the fit of the model at individual points in the experimental region (say R) where the data values are obtained. Given the data vector $\mathbf{y} = (y_1, y_2, ..., y_n)'$, the ith raw residual is defined as $y_i - \hat{\mu}_i$, where $\hat{\mu}_i$ is the maximum likelihood estimate of μ_i.

Since Var(Y_i) is not constant under Generalized Linear Models (GLMs), raw residuals are usually not used. The following two types of residuals were considered;

1. Pearson's residuals

$$r_{i,p} = \frac{y_i - \hat{\mu}_i}{\sqrt{V(\hat{\mu}_i)}}, i = 1, 2, ..., n \tag{3.20}$$

where $\sum_{i=1}^{n} r_{i,p}^2$ is equal to χ^2. When $\alpha(\psi) = \psi$, the quantity $r_{i,p}/\sqrt{\psi}$ is called the ith $(i = 1, 2, ..., n)$ scaled Pearson's chi-square residual. In this case, $\frac{1}{\psi}\sum_{i=1}^{n} r_{i,p}^2 = \chi^2$ which is the scaled Pearson's chi-square.

2. Deviance residuals

$$r_{i,d} = [sign(y_i - \hat{\mu}_i)]\sqrt{d_i}, i = 1, 2, ..., n \tag{3.21}$$

where $d_i \geq 0$ so that $\sum_{i=1}^{n} r_{i,d}^2 = D(\hat{\beta}, y)$, the deviance for the fitted model. Thus, $\sqrt{d_i}$ represents the square root of the contribution of the ith observation to the deviance D and $sign(y_i - \hat{\mu}_i)$ is the sign of the ith raw residual $(i = 1, 2, ..., n)$. When $\alpha(\psi) = \psi$, $r_{i,p}/\sqrt{\psi}$ is the scaled deviance residual".

(Khuri, 2009, p.487-489)

Meanwhile, all the above models would be captured in one procedure in the R statistical software package.

CHAPTER 4

Results and Discussion

4.1 Preliminary analysis

Due to lack of proper registration systems with information on precise attribution of causes of death, regression-based methods are often employed in producing estimates. A number of experts, including Wardlaw (1999), suggested the use of 'process indicators such as percentage of births attended by trained health workers' as substitutes for maternal deaths. However, Saiffudin and Kenneth (2010) argue that 'process indicators' are not suitable substitutes because their frequency in relation to maternal deaths varies across different settings. For instance, in Asian countries, 34% of deliveries are attended by trained birth attendants, with estimated maternal mortality ratio (MMR) of 540 maternal deaths per 100000 live births, whereas in Sub-Saharan Africa about 35% of the deliveries are attended by trained birth attendants, but recorded an MMR as high as 920 maternal deaths per 100000 live births. Clearly, it is erroneous for one to use percentage of births attended by trained health attendants as substitutes for maternal mortality. This study therefore employed the generalised linear models (GLMs) to estimate the MMR for the 10 regions of Ghana.

Maternal mortality rate (number of maternal deaths per 100000 women in fertility age) was first estimated independently for the 10 regions in Ghana and then determined the maternal mortality ratio (number of maternal deaths per 100000 live births) using direct method approach. The results are displayed below;

$$\text{Maternal Mortality Rate(MMRate)} = \frac{\text{Total Maternal Deaths}}{\text{WIFA}} \times 100000\text{WIFA}$$

Maternal Mortality Ratio(MMR)

$$= \frac{\text{Total Maternal Deaths}}{\text{Total Livebirths}} \times 100000\text{livebirths}$$

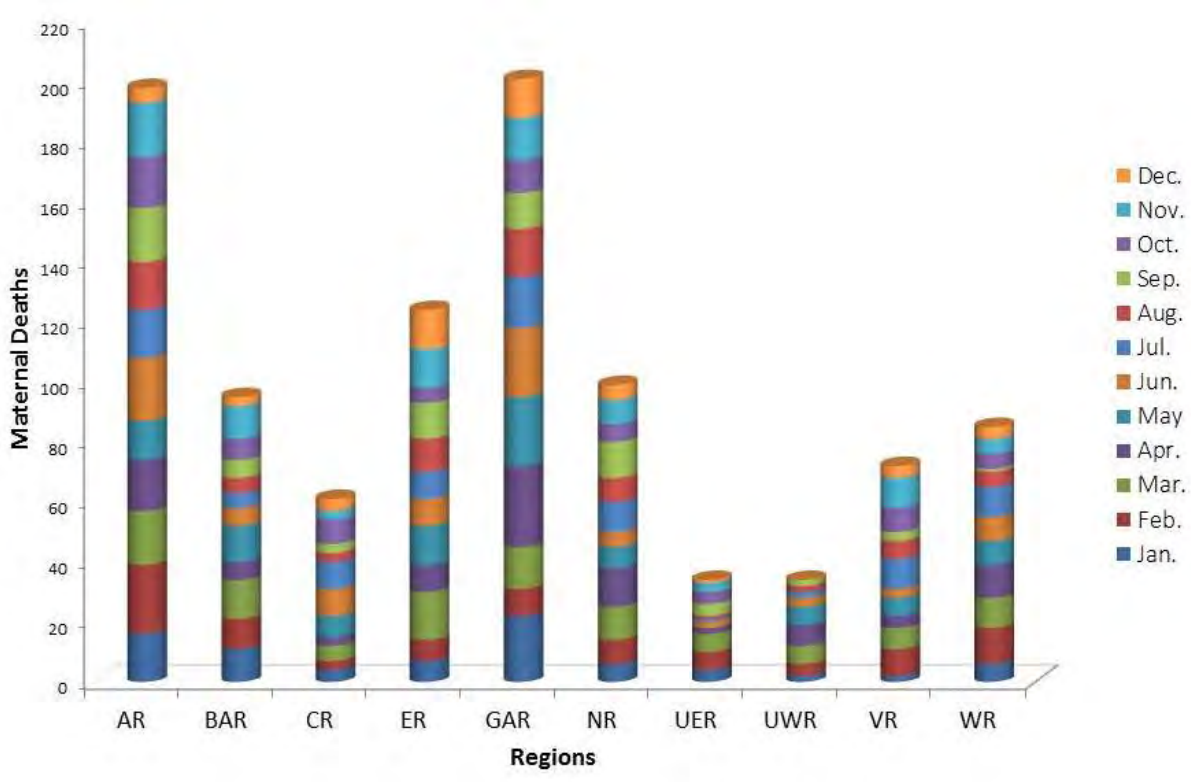

Figure 4.1: Bar Plot of Monthly Maternal Deaths by Region for 2013

Ghana recorded the highest number of maternal deaths, 106 and 116, in march for both 2013 and 2016 respectively. The Greater Accra Region recorded the highest number of maternal deaths in 2013 and 2016, with 201 and 197 maternal deaths respectively.

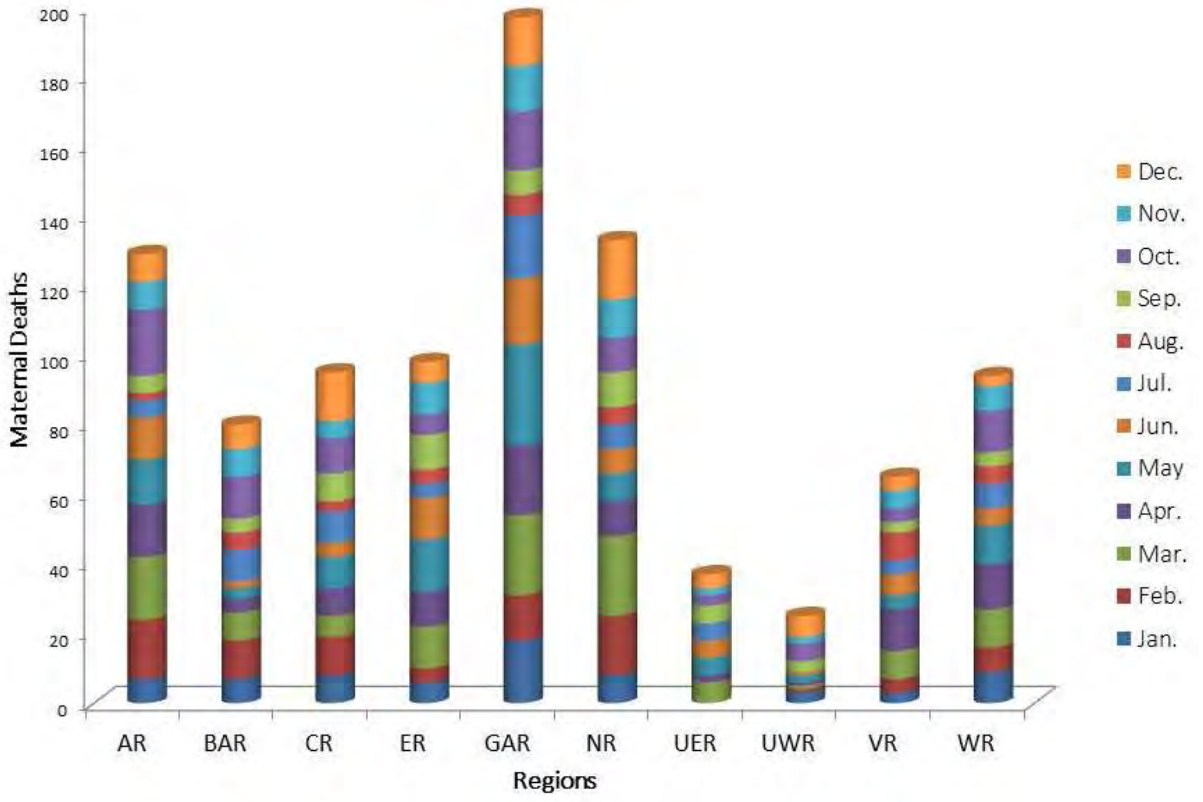

Figure 4.2: Bar Plot of Monthly Maternal Deaths by Region for 2016

The upper West Region recorded the least number of deaths both in 2013 and 2016. Six regions (Ashanti, Brong Ahafo, Eastern, Greater Accra, Upper West and Volta) have shown a steady decline in maternal deaths from 2013 to 2016. However, the remaining four regions(Central, Northern, Upper East and Western) have increased in maternal deaths. Generally, the country has reduced from 1003 to 953 maternal deaths from 2013 to 2016 respectively.

For the data with attribution of death, Hypertensive disorder was the leading cause of maternal death (27.9%) followed by Hemorrhage with 22.1%. The remaining factors are as follows; Abortion (12.8%), Sepsis (0.7%), Ruptured ectopic pregnancy (0.2%) and others (36.3%). Figure 4.3 shows a graph of maternal mortality by attribution of cause of death.

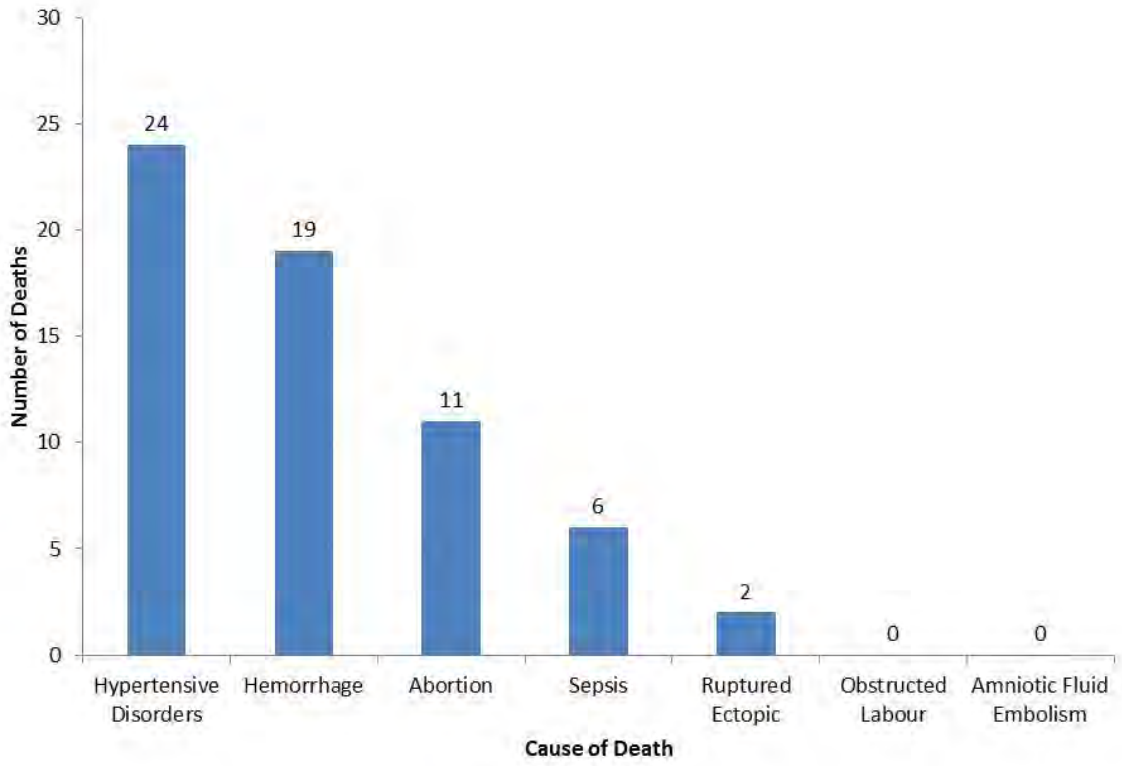

Figure 4.3: Bar Plot of Maternal mortality by death attribution

Table 4.1: Maternal Mortality Rate by Region (2013 & 2016)

Region	MMRate (2013)	MMRate (2016)	WIFA(2013)
UER	26.6	27.3	127824
UWR	42.0	27.9	80906
NR	46.2	48.3	214113
VR	40.6	38.2	177148
BAR	58.1	44.1	163587
AR	34.4	22.1	574964
ER	76.3	59.7	162604
CR	32.3	47.0	188999
WR	32.0	35.0	265761
GAR	26.2	19.5	768562

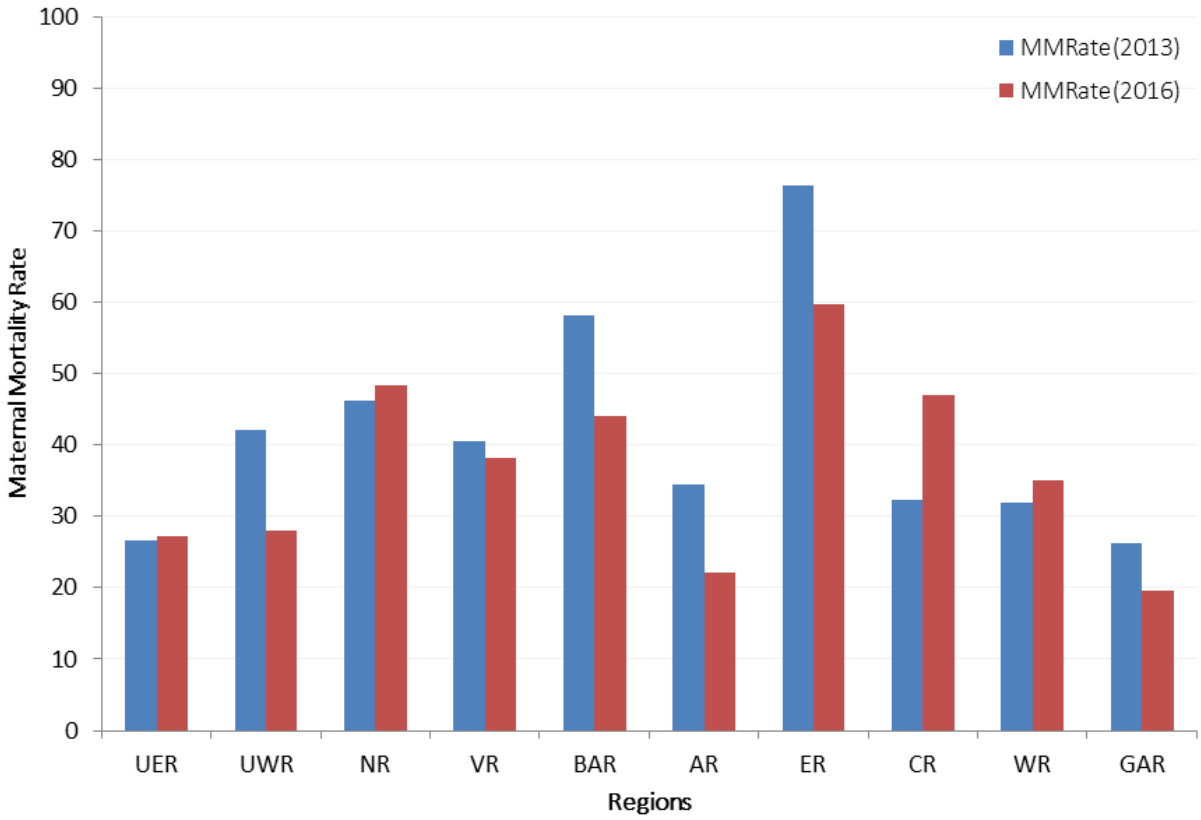

Figure 4.4: Maternal Mortality Rates by Region

Table 4.2: Maternal Mortality Ratio by Region (2013 & 2016)

Region	MMR (2013)	MMR (2016)	WIFA(2016)
UER	870.5	197.7	135738
UWR	286.5	178.7	89699
NR	332.2	402.9	275294
VR	750.9	445.3	185892
BAR	346.2	293.5	174449
AR	356.2	258.7	584466
ER	590.3	461.8	162604
CR	399.1	421.1	201994
WR	316.5	314.2	268658
GAR	317.2	244.4	1011628

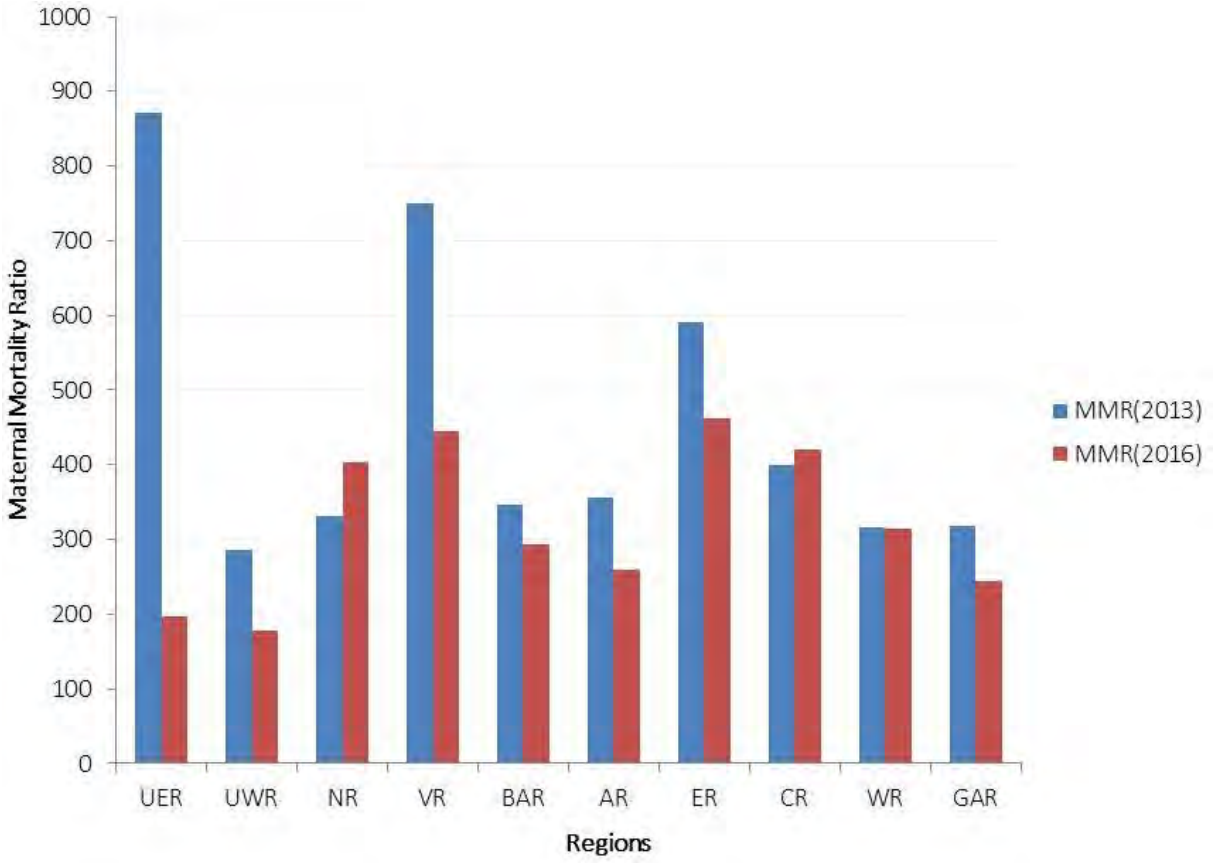

Figure 4.5: Maternal Mortality Ratio by Region

Maternal mortality rates (MMRate) indicate the risk of death per woman, whereas maternal mortality ratio (MMR) shows the risk of death per pregnancy. Upper East Region and Upper West Region have almost the same MMRate (27.3 and 27.9 per 100000 women) for 2016 but have different number of women in fertility age (135738 and 89699) respectively. Regions with high number of women in fertility age mostly have comparatively low MMR estimates. For instance women in Western Region seem to have a lower risk of maternal death than women in Central Region, considering their MMRs- 314.2 and 421.1 respectively.

4.2 Data description and statistics

The 'R' statistical software was employed in analyzing and fitting Generalized Linear Models for maternal death cases. The data were obtained from the District

Health Management Information System(DHMIS) and Ministry of Health's 2016 survey report. The data were 2013 and 2016 maternal mortality data, that were broken down by deliveries, deaths, antenatal care attendance, postnatal care attendance, hemorrhage, sepsis, obstructed labour, hypertensive disorder, ruptured ectopic pregnancy and abortion.

Table 4.3 shows the descriptive statistics of the yearly maternal deaths for 2013 and 2016.

Table 4.3: Descriptive statistics for yearly Maternal Deaths in Ghana

Statistic	2016	2013	Statistic	2016	2013
Minimum	25.00	34.00	Sum	955.00	1003.00
Maximum	197.00	201.00	SE Mean	15.70	18.75
1st Quartile	72.5	63.75	Standard dev.	49.63	59.30
3rd Quartile	121.00	117.75	Variance	2463.39	3516.46
Mean	95.50	100.30	Kurtosis	-0.59	-1.09
Median	94.5	90.00	Skewness	0.46	0.62

The average number of maternal deaths of Ghana in 2013 was 100.3 and 95.5 in 2016. The degree of asymmetry (skewness) of the distribution of the yearly maternal mortality was 0.62 and 0.46 for 2013 and 2016 respectively. This implies that each distribution was skewed to the right. The Kurtosis values (-0.59 and -1.09) indicate that the distributions were platykurtic- very thin compared to the normal distribution.

4.3 Model-based approach

Now, using the generalised linear model, maternal mortality can be estimated indirectly from the predicted values of the model as

$$y = \overline{x}'\beta + \varepsilon \tag{4.1}$$

where ε is an error term and is a vector of auxiliary variables that are mortality predictors measured as an average of the values at the regional level. This method of estimation covers all the data available in the sample, rather than just on data for a particular region. A major setback to the model has to do with the predicted value, which excludes the error term, ε, and hence the heterogeneity across regions.

Thus;

$$E(y) = \overline{x}'\beta \tag{4.2}$$

A weighted estimate of direct and indirect estimators can be obtained using the Random-effects (mixed) models. This provides a balanced estimate.

In the mixed model,

$$y_{mixed} = \overline{x}'\beta + \mu_j + \varepsilon_{ij}, i, j = 1, 2, \ldots, n \tag{4.3}$$

Where μ_j deals with the regions heterogeneity. Both μ_j and ε_{ij} are normally distributed with mean zero and respective variances σ_μ^2 and σ_ε^2.

The best linear unbiased estimation (BLUE) from the mixed model is given as

$$y_{jBLUE} = \overline{x}_j'\beta + \alpha(\overline{y}_j' - \overline{x}_j'\beta) = \alpha\overline{y}_j + (1-\alpha)\overline{x}_j'\beta \tag{4.4}$$

where $\alpha_j = \frac{\sigma^2_{\mu(j)}}{(\sigma^2_{\mu(j)}+\sigma^2_\varepsilon)}$ is the shrinkage factor for region j.

Variances are usually substituted with asymptotically consistent estimators for the fitted models, since they are typically unknown in practice. Maternal death cases were modeled to their respective determinants using the random-effects

Poisson regression model under generalized mixed models. All necessary variable present in the data, based on McCarthy and Maine's conceptual framework for analyzing determinants of maternal deaths, were included in the model. The independent variables were; antenatal care attendants (AA), Postnatal care attendants (PA), and number of surrounding villages accessing health care (NSAH).

The random-effects Poisson model that was fitted is as shown in equation 4.5

$$log(y_{ij}) = \beta_0 + \beta_1 AA + \beta_2 PA + \beta_3 NSAH + V_j + log(Py) \tag{4.5}$$

where β_i, $(i = 1, 2, 3)$, represent the estimated model coefficients and $log(Py)$ is the offset term. V_j is the residual error for region j.

Meanwhile, the Negative binomial regression model was considered as a generalization of the Poisson regression, since it has the same mean structure as the Poisson regression and it has additional parameter to model over-dispersion if it occurs. The following results were obtained using the Negative binomial regression model

Table 4.4: Model estimates for the Regression coefficients and their P-values

	2016		2013	
Variable	Coefficient est.	P-value	Coefficient est.	P-value
AA	0.0586601	0.00518	0.0382974	0.11637
PA	0.0443904	0.00686	0.0630163	0.00112
NSAH	0.0003172	0.44808	0.0006544	0.05206

AA- Antenatal Attendance, PA- Postnatal Attendance, NSAH- Number of surrounding villages Assessing Health care

From the table, in 2016 the variables Antenatal Attendance and Postnatal Attendance has coefficients 0.0586601 and 0.0443904, which are statistically significant. This follows that for each one-unit increase in Antenatal Attendance and Postnatal Attendance, the expected log counts of the number of deaths

increase by approximately 0.06 and 0.04 respectively. However, in 2013, only Postnatal Attendance was statistically significant with a coefficient estimate of approximately 0.063. So for each one-unit increase in Postnatal Attendance in 2013, the expected log count of maternal deaths increased by 0.063. The variable, Number of Surrounding Villages Assessing Health care(NSAH) was not statistically significant for both 2013 and 2016.

To determine if NSAH itself, overall, is statistically significant, I compared a model with and without NSAH. The one degree-of-freedom chi-square test (P-value = 0.0674) shows that NSAH is not statistically significant predictor of maternal deaths.

The interval estimates of the model coefficients were obtained by profiling the likelihood function. The results are displayed in the table below

Table 4.5: Confidence intervals for the model coefficients

	2016		2013	
Coefficient	2.5%	97.5%	2.5%	97.5%
Intercept	2.491328	3.834098	2.571552	3.638880
AA	0.013303	0.104258	−0.009075	0.0863239
PA	0.011540	0.079398	0.0256604	0.102839
NSAH	−0.000496	0.001118	−0.000004	0.001313

AA- Antenatal Attendance, PA- Postnatal Attendance, NSAH- Number of surrounding villages Assessing Health care

4.4 Model Estimation and Fitting

The Negative binomial models assume that the conditional means are not equal to the conditional variances. This inequality is captured by estimating a dispersion parameter that is held constant in a Poisson model. Thus, the Poisson model is actually nested in the Negative binomial model. The Likelihood Ratio Test (LRT) was used to relate these two and tested this model assumption. This was accomplished by running the model as Poisson. The results were as follows;

Table 4.6: Model Estimates of suggested GLM's models with their Log-likelihoods and P-values

	2016			2013		
Model	Intercept	P-value	Log-l.	Intercept	P-value	Log-l.
Poisson	3.388	$2e^{-16}$	−59.883	3.241	$2e^{-16}$	−56.895
Neg. binomial	3.155	$2e^{-16}$	−45.225	3.099	$2e^{-16}$	−44.558

The associated chi-squared values estimated from

$$2 \times (\text{logLik(Negative binomial)} - \text{logLik(Poisson)})$$

were approximately 24.67 using 2013 data and 29.32 using 2016 data. These strongly suggest that the Negative binomial model, estimating the dispersion parameter, was more appropriate than the Poisson model.

4.5 Diagnostic checking of the model

The adequacy of the regression model was checked by plotting the residuals of the model.The randomly dispersed points in the the residual plots suggest that the generalized linear model was appropriate or fit for the data.

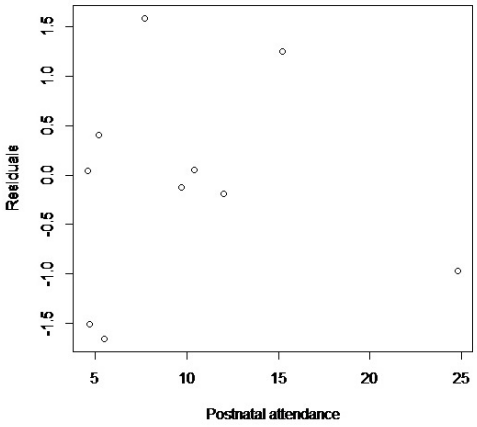

Figure 4.6: Residual plot one.

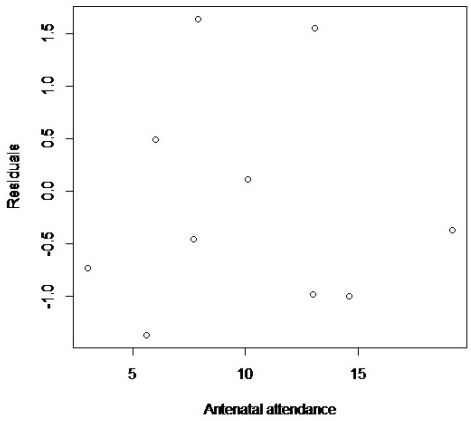

Figure 4.7: Residual plot two.

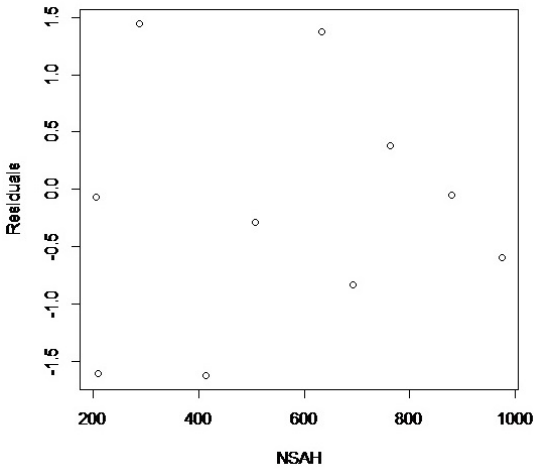

Figure 4.8: Residual plot three.

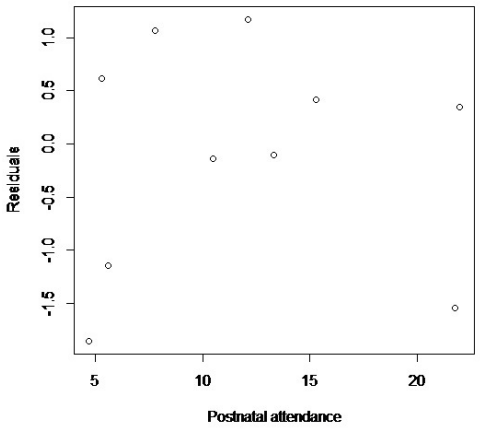

Figure 4.9: Residual plot four.

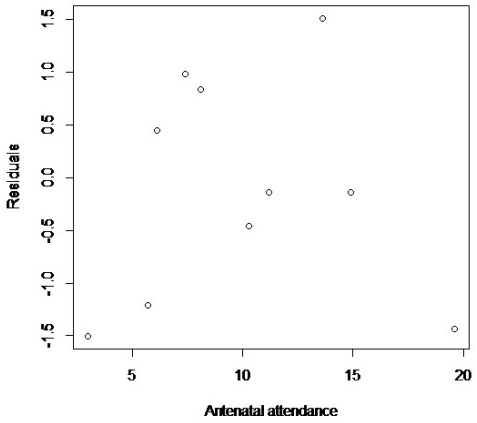

Figure 4.10: Residual plot five.

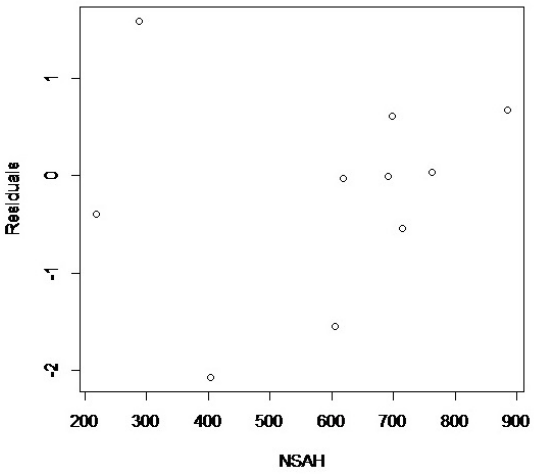

Figure 4.11: Residual plot six.

CHAPTER 5

SUMMARY CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a summary of the findings, conclusions drawn from the findings as well as recommendations.

5.2 Summary

The purpose of the study was to measure the relation between possible medical and social factors affecting maternal deaths and to create interval estimates of the risk linked to these factors. Secondary data were obtained from the District Health Management Information System (DHMIS) in the ten Regions of Ghana. The 'R' statistical analysis software was employed in fitting Generalized Linear Models and analysing the maternal death cases. The data were 2013 and 2016 maternal mortality data, that were broken down by deliveries, deaths, antenatal care attendance, postnatal care attendance, hemorrhage, sepsis, obstructed labour, hypertensive disorder, ruptured ectopic pregnancy and abortion.

The Maternal Mortality Ratio (MMR) for Ghana reduced from 379 in 2013 to 306 in 2016 (about 19% reduction). This trend in reduction suggests that Ghana might not attain the Sustainable Development Goal (SDG) target of 70 per 100000 live births by 2030.

5.3 Conclusion

This paper evaluated the relationship between possible medical and social factors contributing to maternal mortality and has provided interval estimates of the risk linked to these factors. Antenatal care and Postnatal care have proven to be significant determinants of maternal deaths. A conceptual framework was therefore developed to guide policy makers to find high-risk areas, define action plans, distribute resources efficiently and set targets based on priorities in order to achieve the Sustainable Development Goal (SDG) target of at most 70 maternal deaths per 100000 live births by 2030. Eastern Region was leading in Maternal Mortality Ratio (461.8 per 100000 live births), followed by the Volta Region with an MMR of 445.3 per 100000 live births. Upper West Region recorded the lowest MMR of 178.7 per 100000 live births in 2016.

5.4 Recommendations

National Maternal Mortality Ratios alone hardly give important information on areas where major problem of maternal mortality is found, who is involved, what the contributing factors are, and above all what sub-national differences occur (Houston et al., 2013). It is against this backdrop that the analysis is on regional basis.

Since Antenatal care and Postnatal care have been found to be significant determinant of maternal deaths in the country, there is the need to carry prenatal care and health services to areas within the community and provide trained birth attendants and mobile clinic vans for the benefits of pregnant women and nursing mothers. The Antenatal care must be one that not only recognizes risks and detects complications, but also gives precise information on recognition of danger signs and on where to go in case of emergency. In furtherance, the government of Ghana's free antenatal care service should be

revived, and if possible, medical care for nursing mothers should be free of charge as well. This is essential because effective antenatal and postnatal care services could lead to the detection and prevention of medical factors that often result in complications, which eventually place pregnant women and nursing mothers in high category for death.

For effective antenatal and postnatal care services, quality data are required to track short term progress of the measures put in place. The following framework, Maternal Mortality Risk Factor Management System (MMRFMS), is therefore recommended.

The MMRFMS would help us

- in estimating National, Regional and District levels maternal mortality rates and maternal mortality ratios.
- to identify risk factors contributing to maternal mortality.
- to identify locations where the greatest and immediate attention on maternal mortality is mostly needed.
- to come out with intervention strategies

The Maternal Mortality Risk Factor Management System is outlined in the diagram below;

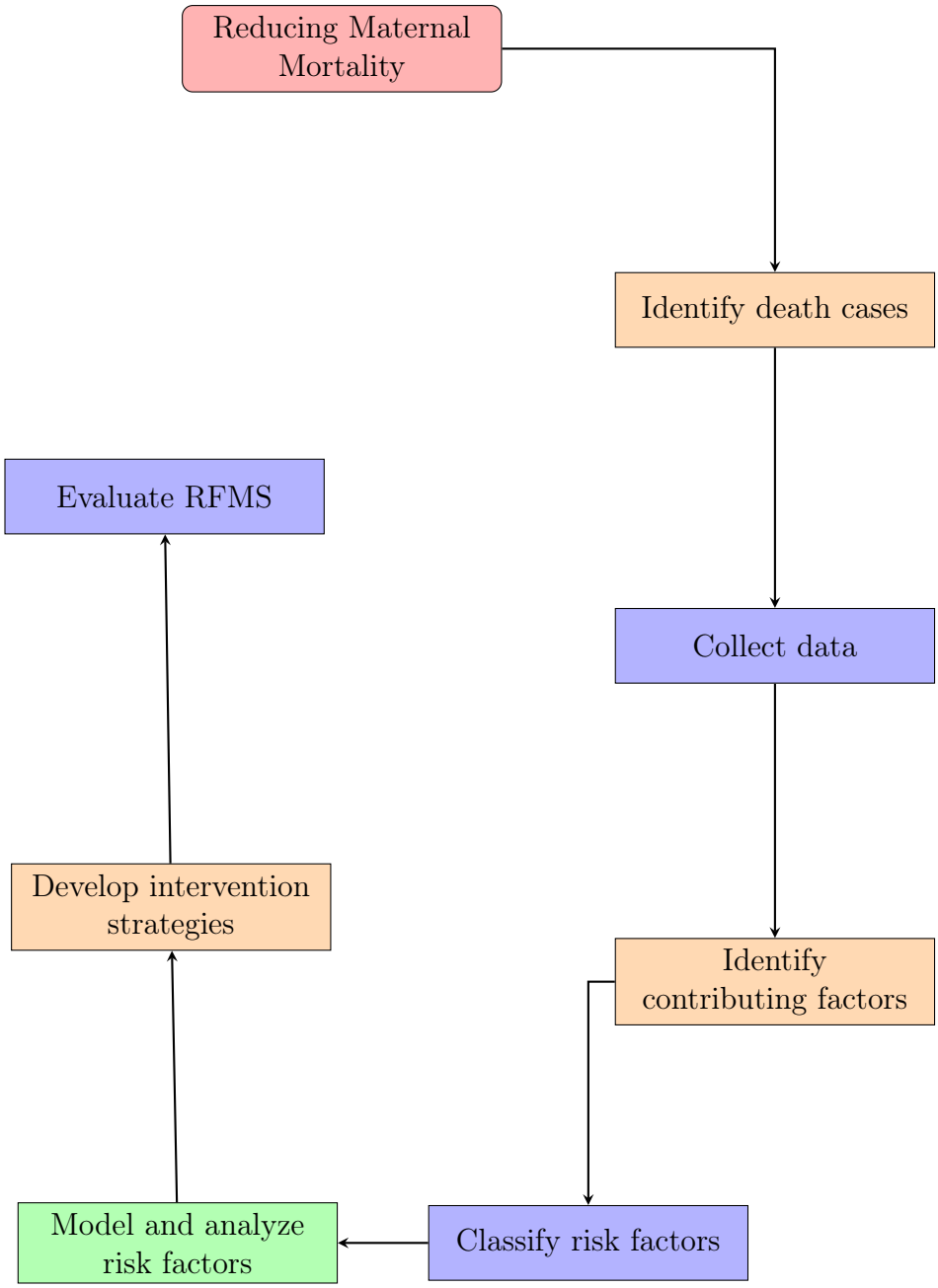

Figure 5.1: Maternal Mortality Risk Factor Management System

The broad objective is to eliminate maternal mortality. This is possible only when the contributing factors are clearly identified, classified and modeled for the necessary intervention strategies be developed to resolve these factors. The stages in the chart are briefly explained below;

stage 1. Identify maternal death cases, centred on the World Health Organization's definition- the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes.

stage 2. Data are required to follow short term progress, clearly defined actions and intervention evaluation. Hence, collect data on maternal deaths using a well-designed questionnaire or by adopting my data collection instrument (Fig. 5.2 on page 53).

stage 3. Identify causes (risk factors) of maternal deaths based on McCarthy and Maine's conceptual framework for identifying maternal mortality determinants. This could be achieved through maternal deaths reviews and confidential inquiries.

stage 4. Classify the risk factors into social and biological or into minor and major categories, so that the needed intervention strategies could easily be developed and implemented to avoid subsequent maternal deaths.

stage 5. Model and analyze the risk factors.

stage 6. Develop intervention strategies based on the analyses results. For instance, if in a particular region or district, lack of Skilled Health Personnel is identified as a contributing factor, then the central government must see to this.

stage 7. Evaluate the MMRFMS. There is the need to evaluate the system to identify areas that require improvements.

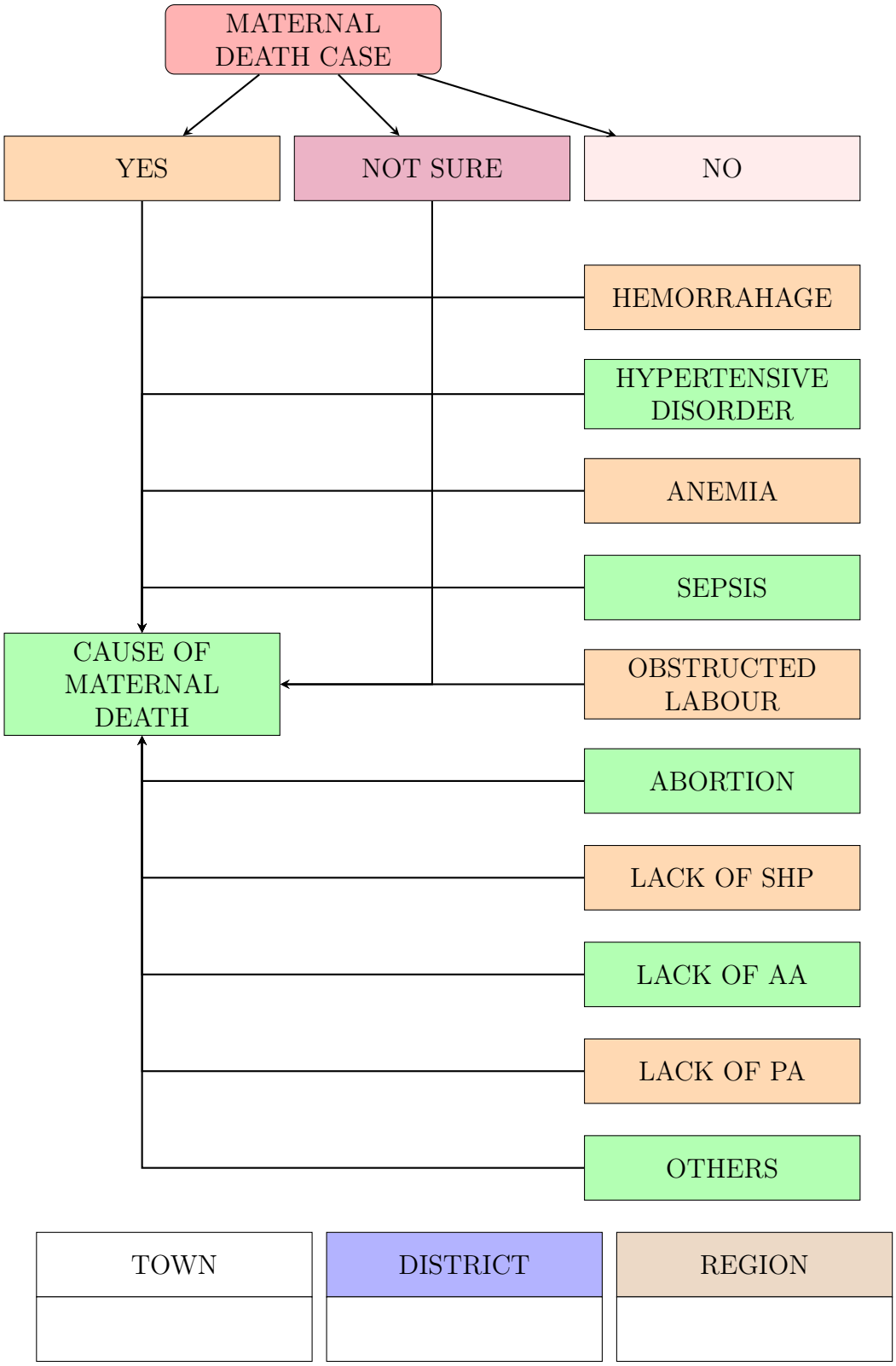

Figure 5.2: Maternal Mortality Data Collection Instrument

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APPENDIX

Table 5.1: Demographic Statistics by Region(2016)

Region	Population	Deliveries	Deaths	NSAH	WIFA
UER	565576	18712	37	606	135738
UWR	397284	13993	25	404	89699
NR	998926	33013	133	885	275294
VR	767929	15946	71	714	185892
BAR	726872	26233	77	219	174449
AR	2435273	49868	129	698	584466
ER	677518	21005	97	762	162604
CR	839700	22561	95	692	201994
WR	1113463	29919	94	619	268658
GAR	2895815	80605	197	288	1011628

Table 5.2: Demographic Statistics by Region(2013)

Region	Population	Deliveries	Deaths	NSAH	WIFA
UER	537431	3906	34	209	127824
UWR	340461	11867	34	413	80906
NR	489173	29798	99	879	214113
VR	712248	9588	72	975	177148
BAR	681605	27440	95	206	163587
AR	2373696	55584	198	634	574964
ER	677518	21005	124	762	162604
CR	789367	15285	61	692	188999
WR	1065646	26857	85	508	265761
GAR	2560001	63355	201	288	768562

Table 5.3: Percentage Distribution of General Attendance(2016)

Region	Antenatal Attendance	Postnatal Attendance
UER	5.7	5.6
UWR	3.0	4.7
NR	14.9	12.1
VR	6.1	5.3
BAR	10.3	10.5
AR	19.6	15.3
ER	8.1	7.8
CR	7.4	21.8
WR	11.2	13.3
GAR	13.6	22.0

Table 5.4: Percentage Distribution of General Attendance(2013)

Region	Antenatal Attendance	Postnatal Attendance
UER	5.6	5.5
UWR	3.0	4.7
NR	14.6	12.0
VR	6.0	5.2
BAR	10.1	10.4
AR	19.2	15.2
ER	7.9	7.7
CR	7.7	4.6
WR	13.0	9.7
GAR	13.1	24.8

Table 5.5: Causes of Maternal Deaths at KBTH from 2011 to 2013

Cause	2011	2012	2013
Hypertensive disorders	33	26	24
Hemorrhage	37	20	19
Abortion	13	8	11
Sepsis	5	2	6
Ruptured ectopic	2	5	2
Obstructed labour	0	1	0
Amniotic F. Embolism	0	1	0
sickle cell diseases	10	7	4
Anaemia	9	5	1
HIV/AIDS	2	7	4
Cardiac Arrest	2	0	0
Hepatitis	2	1	0
Diabetes	0	0	0
Pulmonary Embolism	2	0	5
Meningitis	0	1	2
Others	2	1	8