UNIVERSITY OF CAPE COAST

NEONATAL MORTALITY IN THE KINTAMPO NORTH AND SOUTH DISTRICTS: ANALYSIS OF COMMUNITY, COMPOSITION AND SPATIAL FACTORS

GEORGE ADJEI

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BY

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Thesis submitted to the Department of Population and Health, Faculty of Social Sciences, College of Humanities and Legal Studies, University of Cape Coast, in partial fulfilment of the requirements for the award of Doctor of Philosophy Degree in Population and Health.

FEBRUARY 2020

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: .... Date: ....

Name: George Adjei

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature: .... Date: ....

Name: Dr. David Teye Doku

Co-Supervisor's Signature: ....Date: ....

Name: Prof. Eugene K.M. Darteh

ABSTRACT

Communities and their composition (individuals and households) coupled with spatial factors have impact on neonatal mortality. However, considering the smallest health administrative units as communities (sub-districts) and investigating the impact of these communities, their composition and spatial factors on neonatal mortality in Ghana has not been considered. Therefore, the aim of this study was to investigate the effect of communities, households, individuals and spatial factors on the risk of neonatal mortality in the Kintampo Districts of Ghana. Multilevel cox frailty model and Kulldorf methods were used to analyse longitudinal data (January 2005-December 2014) involving 30,132 neonatal singletons with 634 deaths. The study found that, the highest risk of neonatal mortality within the Kintampo Districts occurred in the first three days of life. In addition, risk of neonatal mortality was found to be higher in the early neonatal period (1-8 days) than in the late neonatal period (9-28 days). With regards to individual level factors, neonates whose mothers had previous adverse pregnancy had a higher risk of mortality compared to neonates whose mothers did not experience any previous adverse pregnancy. Also, neonates whose mothers did not receive tetanus toxoid injection during pregnancy had a higher risk of mortality compared to those whose mothers received tetanus toxoid injection. However, neonates whose mothers had secondary education or higher had a lower risk of mortality compared to those whose mothers had no formal education. Also, the neonates belonging to the third quintile households had a lower risk of mortality compared to neonates from poorest households. There was a significant clustering of deaths attributable to asphyxia and prematurity. The findings of the study suggest risk of neonatal deaths at the individual and household levels and also cause-specific neonatal mortality clustering in some parts of the Kintampo Districts. More women in the Kintampo Districts should be encouraged to attend antenatal clinics and visit health facilities for early postnatal care.

KEY WORDS

All-cause neonatal mortality clustering

Cause-specific neonatal mortality clustering

Community level factors

Household level factors

Individual level factors

Neonatal mortality

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DEDICATION

To all who actually made this work a success

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ANC	Antenatal Clinic
CBVs	Community-Based Volunteers
CHNs	Community Health Nurses
CHOs	Community Health Officers
CHPS	Community Based Health Planning and Services
CKIs	Community Key Informants
CSDH	Commission on Social Determinants of Health
DHIMS	District Health Information Management System
DHMT	District Health Management Team
ELF	Ethno-linguistic Fractionalisation
GDHS	Ghana Demographic and Health Survey
GHS	Ghana Health Service
GIS	Geographical Information System
GPS	Global Positioning System
GSS	Ghana Statistical Service
HDSS	Health and Demographic Surveillance System
KHDSS	Kintampo Health and Demographic Surveillance System
LBW	Low Birth Weight
MDG	Millennium Development Goal
MoH	Ministry of Health
NM	Neonatal Mortality
PCA	Principal Component Analysis

SDG	Sustainable Development Goal
TBA	Traditional Birth Attendant
TTI	Tetanus Toxoid Injection
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
VA	Verbal Autopsy
VPM	Verbal Post Mortem
WHO	World Health Organisation

CHAPTER ONE

INTRODUCTION

Background to the Study

Over the past two decades, both under-five and neonatal mortality (NM) rates have been declining (UNICEF, 2014). However, the rates at which neonatal mortality is declining is slower than that of under-five mortality (UNICEF, 2014). This phenomenon of slower decline in neonatal mortality has made neonatal mortality relatively stagnant and as a result of that many regions in the world including sub-Saharan Africa could not achieve Millennium Development Goal (MDG) 4 of reducing under-five mortality by two-thirds in 2015 (UNICEF, 2015).

Globally, the number of neonatal deaths declined substantially from 5.1 million in 1990 to 2.7 million in 2015 (WHO, 2016). However, the decline in neonatal deaths in comparison with post-neonatal deaths has been slower. Whereas post-neonatal mortality decreased by 58%, neonatal mortality declined by 47% (WHO, 2016). About one million neonatal deaths occurred in 2015 alone and this is equivalent to 2740 neonatal deaths per day (UNICEF, 2016). This makes neonatal mortality a threat to under-five survival and study of its risk factors are therefore necessary for intervention programmes and further research. It is projected that if the current trends continue, approximately half of the projected 69 million under-five deaths from 2016 to 2030 will occur during the neonatal period (WHO, 2016). The SDG 3.2 has a target of ending preventable newborn and under-five deaths by 2030 with the aim of all countries reducing neonatal and under-five mortality rates by 12 per 1000 live births and 25 per 1000 live births respectively

(UNICEF, 2015). Considering that the target of MDG 4 is not achieved, maintaining the current trend of reduction poses a global threat to the attainment of SDG 3.2.

Sub-Saharan Africa bears the most brunt of neonatal mortality and accounts for 38% of the global neonatal deaths (UNICEF, 2014). Over the past two decades, the region has also been experiencing the phenomenon of slower decline in neonatal mortality (You, Hug, Ejdemyr, Beise, 2015); making it one of the regions which require huge resources to reducing neonatal mortality significantly.

Ghana which is also a country in sub-Saharan Africa is no exception with regards to burden of neonatal mortality. Neonatal mortality accounts for 48% of under-five deaths in Ghana and the rate of neonatal deaths is twice that of post-neonatal deaths (Ghana Statistical Service (GSS), Ghana Health Service (GHS) & ICF International (ICFI), 2015). Besides, between 2008 and 2014, neonatal mortality rates declined marginally by 3 percentage points as compared to post-neonatal and under-five mortality rates that declined significantly by 38 and 25 percentage points respectively (GSS, GHS & ICFI, 2015). These reasons make neonatal mortality burden in Ghana high and unless concerted efforts are made, Ghana will not be able to achieve the Sustainable Development Goal (SDG) 3 of reducing under-five and neonatal mortality rates to 25 and 12 per 1,000 live births respectively (United Nations, 2015). A vast majority of neonatal deaths ranging between 98% and 99% occur in the low and middle income countries (Lawn, Cousens, & Zupan, 2005; UNICEF, 2012) of which more than fifty percent (50%)

of these deaths occur within the communities, often the home (Lawn, Cousens, & Zupan, 2005).

Since a large proportion of these neonatal deaths occur at home, it requires a systematic study of all possible factors in the communities that are likely to predispose them to death (Bashir et al., 2013; Selemani et al., 2014). In line with literature, a community (or cluster) may be any well-demarcated geographical area such as a village, district, enumeration area, administrative district et cetera (Roux, 2001; Duncan, Jones & Moon, 1998). Variation in health outcomes in terms of geographical context may be due to contextual effect (or community level effect) or compositional effect (individual or household level effect) (Roux, 2001; Duncan, Jones & Moon, 1998). This makes it necessary to adjust for the effect of composition when assessing risk factors for a particular health outcome at the community level and vice versa (Duncan, Jones & Moon, 1998). In the nutshell, variation in health outcomes between individuals in different communities may be due to effect of community or compositional factors.

The major risk factors of neonatal mortality include preterm birth, infections, asphyxia, low birthweight and maternal complications during labour (Lawn, Cousens & Zupan 2005; Liu et al., 2012). Findings of research have also shown that individual level, household and community level factors also influence neonatal mortality (Biering-Sorensen et al., 2012; Kananura et al., 2016; Kayode et al., 2014; Mekonnen, Tensou; Telake, Degefie, 2013; Rahman & Huq, 2009; Vandresse, 2006). In a study carried out in Bangladesh, Rahman and Huq (2009) were able to demonstrate that lower household size, maternal delivery related complications, higher order birth and male neonates were associated with higher neonatal mortality. Mekonnen et al.'s study (2013) in Ethopia revealed that neonates delivered in specific regions (Amhara, Benishangul Gumuz and Tigray) of Ethiopia had higher risk of death. Additionally, the study found that male sex, neonates who had a preceding birth interval of less than 2 years and were born to younger mothers (less than 18 years) were more likely to die. Besides, neonates born to mothers who received two or more tetanus toxoid injection before delivery and to mothers with secondary education or higher had lower risk of death. Kayode and colleagues (2014) conducted a study in Ghana and were able to demonstrate that neonates whose mothers dwelt in a community of high socioeconomic deprivation were associated with higher risk of death. In addition, the study found that neonates with inadequate preceding birth interval, low birthweight, born to grand multiparous mothers and were not breast-fed had increased risk of death.

However, neonates born to mothers with adequate utilization of antenatal, delivery and postnatal services had decreased risk of death. Therefore, integrating community, household and individual level factors will explain the mechanism leading to neonatal mortality exhaustively. Some other individual level factors associated with higher risk of neonatal deaths are maternal age (young or old age), breastfeeding practices (late or non-exclusive breastfeeding), previous adverse pregnancy, preterm birth, late or no reception of BCG vaccine and high birth order (Biering-Sorensen et al., 2012; Kananura et al., 2016; Kayode et al., 2014; Mekonnen, Tensou; Telake, Degefie, Bekele, 2013; Neupane & Doku, 2014; Rahman & Huq, 2009). Additionally, some other household level factors predisposing neonates to higher risk of death include, inadequate portable water, poor sanitary facilities and crowding (Golding, Greenwood, McCaw-Binns, Thomas, 1994; Vajpayee & Govila, 1987; Rahman & Huq, 2009). Also, other community level factors found to be associated with higher risk of neonatal deaths includes poor sanitary conditions in the community, inadequate safe water, high illiteracy rate, high ethnic heterogeneity (or fractionalization), high poverty levels and large distance to health facilities (Boco, 2010; Kayode et al., 2014; Kwaraji, Cousens, Berhane, Mulholland, Edmond 2012; Tymicki, 2009). The mechanism underlying the influence of male sex on higher risk of neonatal mortality is primarily due to the biological make-up of males (Singh, Kumar & Kumar, 2013). Also, competition among neonates for parental resources and their mothers' attention is the underlying mechanism regarding the association of birth order with risk of neonatal death.

Several factors explain the mechanism underlying the relationship between maternal education and neonatal mortality. The factors include the fact that women with higher education are more likely to access prenatal care, knowledgeable and skillful in child healthcare, defy taboos and negative cultural practices and able to afford quality healthcare (Buor, 2003; Kravdal, 2004). Moreso, association between maternal age and risk of neonatal mortality is due to physiological immaturity of young mothers and maternal depletion of older women as a result of giving birth repeatedly and at short intervals (Gyimah, 2002b; Tymicki, 2009). Tetanus toxoid vaccine received by mothers during pregnancy also produces antitoxin which is transported to the fetus which ultimately gives the newborn protection against tetanus during the neonatal period (Roper, Vandelaer. Gasse, 2007). In addition, the pathway of the relationship between previous adverse pregnancy of women and risk of neonatal death is explained by the biological deficiency in women's reproductive capacity (Tymicki, 2009; Vandresse, 2006).

Spatial variation may also lead to differences in mortality among neonates (Ameida, Gomes & Nascimento, 2014; Sartorius et al, 2010). Individuals and households in a particular community tend to have common exposures that may lead to risk in neonatal mortality changing from one community to the other (Sartorius et al, 2010). Findings of studies have already revealed that the spatial effect on infant and child morbidity are due to counties, villages, administrative districts or regions among others. Although spatial variation is prone to ecological fallacy (Voss, 2007), it is important for health administrators and programme managers since they use the information for planning purposes.

Problem Statement

Differences in child health outcomes may be due to differences in community, household or individual characteristics (Boco, 2010; Liwin & Houle, 2019). However, it is widely recognised that socio-economic attributes, physical structures and the environmental attributes of the community shapes the health outcomes of children in the community (Adedini et al., 2015; Huda, Tahsina, Arifeen, Dibley, 2016; Kayode et al., 2014; Kravdal, 2004; Manda, 2001; Mekonnen, Tensou; Telake, Degefie, 2013; Sastry, 1996; Singh, Kumar & Kumar, 2013; Titaley et al., 2008; Van de Poel, O'Donnell, Van Doorslaer, 2009; Vandresse, 2006; Zanini, de Moraes, Giugliano, Riboldi, 2011). Provision of healthcare services, healthcare infrastructure and public services in the community such as sanitation, electricity, water supply, health facilities and availability of healthcare professionals are important community factors that are linked to child differential health outcomes. For instance, availability of health facility and healthcare professionals in a community have the potential to improve the survival of children in the community. Sastry's (1996) study in Brazil revealed that communities (Municipalities) with public garbage collection and cleaning services had very low risk of child mortality. Besides negative cultural practices of communities form another pathway that distinguishes child mortality (Boco, 2010; Say & Raine, 2007).

The community effect on child mortality has been far advanced in theoretical works (Ellen, Mijanovich, & Dillman, 2001; Mosley & Chen, 1984; Vandresse, 2006) and empirical literature (Adedini et al., 2015; Huda, Tahsina, Arifeen, Dibley, 2016; Kayode et al., 2014; Kravdal, 2004; Manda, 2001; et al., 2013; Singh et al., 2013; Titaley, Dibley, Agho, Roberts, Hall, 2008; Liwin & Houle, 2019). In her theoretical work, Vandresse (2006) posited that environmental characteristics such as housing conditions, pollution (air, ground, water and food pollution), climate etc. of the region in which one resides have effects on infant mortality. The conceptual framework of Mosley and Chen (1984) acknowledged the community effect by linking child mortality and socio-economic determinants of individual, household and community through proximate factors. Regarding empirical literature, Lalou (1997) posited that the quality of the community environment affects neonatal mortality.   Van de Poel and colleagues (2009) using data from six francophone countries in sub-Saharan Africa were able to establish that communities where infants are born affect their survival. In a study conducted in India, Kravdal (2004) was able to demonstrate that communities having women with higher average duration of education had reduced risk of child mortality. Adedini et al.'s (2015) study in Nigeria showed that community level factors such as proportion of educated mothers and proportion of hospital deliveries have effect on infant and child mortality. Moreso, studies by Huda et al. (2016), Kayode et al. (2014), Mekonnen et al. (2013), Kamal (2012) and Singh et al. (2013) have all been able to demonstrate that communities have effect on neonatal mortality. Liwin and Houle (2019) in their recent work in Sierra Leone, corroborated these findings.

In brief, several physical and social structures of the community have been found to affect the health outcome of children irrespective of the household and individual factors associated with children (Adedini et al., 2015; Huda, Tahsina, Arifeen, Dibley, 2016; Kayode et al., 2014; Kravdal, 2004; Manda, 2001; Mekonnen, Tensou; Telake, Degefie, 2013; Nisar & Dibley, 2014, Singh et al., 2013; Titaley, Dibley, Agho, Roberts, Hall, 2008; Liwin & Houle, 2019; Van de Poel, O'Donnell, Van Doorslaer, 2009). This makes community factors associated with child health risk a key policy tool for the development of public health intervention (Boco, 2010).

Neonatal mortality is a major contributor to under-five mortality (UNICEF, 2015). In Ghana, a newborn dies every 15 minutes (UNICEF Ghana bulletin, 2015) Also, the estimate of neonatal mortality in 2014 shows that Ghana has one of the highest neonatal mortality rates in West Africa (GSS, GHS & ICFI, 2015; You, Hug, Ejdemyr, Beise, Idele, 2015). With the current neonatal mortality rate of 29 deaths per 1000 live births, Ghana's rate is greater than Africa's average rate of 27 per 1000 live births. Between 1990 and 2014, the proportion of neonatal mortality among infants in Ghana increased from 53% to 71% (GSS, GHS & ICFI, 2015). Within the same period, the proportion of neonatal mortality among under-five deaths almost doubled from 28% in 1990 to 48% in 2014 (GSS, GHS & ICFI, 2015). Kintampo Districts located in the middle belt of Ghana are no exceptions and the districts are experiencing a slower decline in neonatal mortality in comparison with post-neonatal mortality (Owusu-Agyei et al., 2012). Post-neonatal mortality in Kintampo Districts declined significantly from 32 deaths per 1,000 live births in 2005 to 21 deaths per 1,000 live births in 2009 (Owusu-Agyei et al., 2012). On the contrary, neonatal mortality declined slightly from 32 deaths per 1,000 live births in 2005 to 31 deaths per 1,000 live births in 2009 (Owusu-Agyei et al., 2012). This indicates that rates of neonatal and post-neonatal mortalities were the same in 2005 in the districts but post-neonatal mortality reduced significantly in comparison with neonatal mortality within the same period. In addition to slower decline in neonatal mortality rates, 42% of neonatal deaths also occur in the communities (KHDSS data, 2014). This makes it necessary for a study to be carried out to investigate community level factors influencing neonatal mortality within the communities of Kintampo. However, individual level factors are nested in household level factors which are in turn nested in community level factors (Babalola & Fatusi, 2009; Kayode et al., 2014). Therefore, investigating the effect of community level factor alone on neonatal mortality may bias the findings

(Babalola & Fatusi, 2009). Babalola and Fatusi (2009) contended that methodologically, it is important to take this nested structure into account. Zanini et al. (2009) affirmed this assertion by stating that failure to consider the correlation of individuals belonging to same group may give spurious results. This is further supported by findings of studies which suggest that variation of health outcomes between communities (or clusters) are due to community factors, compositional factors or both (Ellen, Mijanovich, & Dillman, 2001). Hence in order to elicit differences in neonatal mortality outcomes between communities, it is necessary to investigate individual, household and community level factors affecting neonatal mortality.

Studies on neonatal mortality have been carried out in Ghana (Edmond, Kirkwood, Amenga-Etego, Owusu-Agyei, Hurt, 2007; Kayode et al., 2014; Kirkwood et al., 2013; Manortey et al., 2011; Singh et al., 2013). However, many of these studies rarely considered influence of community together with its composition effects on neonatal mortality outcomes. Only one study to the best of my knowledge considered community and its compositional effects (Kayode et al., 2014). However, that study disregarded the health administration sub-districts (the smallest units of healthcare system administration in Ghana) as proxies for communities (or clusters) whose operations and planning can be strategically scaled up to provide the necessary and well-focused interventions to reduce neonatal deaths in Ghana. Besides, the design of this study is not longitudinal and therefore this study lacks the temporal sequence which can be used to establish causality.

Findings of longitudinal studies provides relevant and reliable information upon which further interventions can be recommended.

One of the strengths of longitudinal studies is following up study participants to establish that, risk factors resulted in the desirous outcome. In addition, children from the same household can be systematically monitored to examine the common set of observed and unobserved risk factors they are exposed to; unlike studies that use survey data where only the index or current child is included due to lack of data on the preceding children. A major factor hindering systematic study of risk factors for neonatal mortality in sub-Saharan Africa, is the lack of good quality longitudinal data for neonatal survival. The Kintampo Health and Demographic Surveillance System (KHDSS) established by Kintampo Health Research Centre (KHRC) has been continuously collecting health and demographic data of the population within the Kintampo North Municipality and South District (hereinafter Kintampo Districts) for the past 16 years. The longitudinal data at KHDSS serves as an excellent material for investigating risk factors of neonatal mortality within the 12 sub-districts in Kintampo which are referred to as communities hereinafter.

Neonatal mortality is also unevenly distributed by geographic region as a result of similar practices and exposure of households or individuals within a particular sub-district (as cited in Padilla, Kihal-Talantikit, Vieira, Deguen, 2016). Generally, communities are spatially referenced and bounded; and also play an important role on the health outcomes of children (and other members of the community) (Arguillas, 2008; Galster, 2001). One of the underlying reasons for different exposures in the communities is that intervention activities of governments and non-governmental organisations are spatially implemented (Galster, 2001). For example, provision of healthcare infrastructure and services and other public services such as electricity, water supply, sanitation and garbage services are provided by governments based on geographically defined communities such as counties, districts, metropolis, sub-districts etc (Boco, 2010). Additionally, the predominant norms and attitudes of the community members towards healthcare also determines child health outcomes (Degefie, Amare, Mulligan, 2014; Gyimah, 2002a). According to Galster (2010), decision-makers alter the supply of resources to communities based on the evaluation of the communities' attitude. Besides, Sanko et al. (2001) have contended that the implementation of public health systems requires knowledge of spatial distribution of child's mortality. The afore-mentioned arguments advanced in the literature makes it important to undertake spatial investigation and identify clusters (village or group of villages) in the Kintampo Districts that are hot-spots (village or group of villages with high rates of health outcomes) for neonatal mortality.

Studies involving spatial distribution of under-five mortality deaths have been carried out in some parts of sub-Saharan Africa (Alabi, Baloye, Doctor, Olugbenga, Oyedokun, 2016; Byass, Fantahun, Emmelin, Molla, Berhane, 2010; Lutambi, Alexander, Charles, Mahutanga, Nathan, 2010; Sankoh, Ye, Sauerborn; Muller, Becher; 2001). In Burkina Faso, Sankoh et al. (2001) found several significant clusters (group of villages) for under-five deaths where potential risk factors of ethnicity, religion and nearest distance to the health facility could not explain it. This finding aligns with a study carried out in Nigeria where under-five mortality clustering for high rates of death were identified in all the six districts considered (Alabi, Baloye, Doctor, Olugbenga, Oyedokun, 2016). However, Alabi et al. (2016) study considered group of compounds as clusters and lack of access to healthcare facilities, proper sanitation and better living conditions were the possible reasons for some of the significant mortality clustering.

Findings of studies on under-five spatial mortality clustering undertaken in Ghana confirm that of studies conducted in other sub-Saharan Africa countries (Adjuik, Kanyomse, Wak, Hodgson, 2010; Arku et al., 2016; Nettey, Zandoh, Sulemana, Adda, Owusu-Agyei, 2010). The spatial mortality clustering studies in Ghana focused on all-cause under-five mortality clustering (Adjuik, Kanyomse, Wak, Hodgson, 2010; Arku et al., 2016; Nettey, Zandoh, Sulemana, Adda, Owusu-Agyei, 2010). However, the highest risk of neonatal mortality in Ghana occurs in the neonatal period (GSS, GHS & ICFI, 2015). Therefore, investigating the spatial distribution of cause-specific and all-cause neonatal mortalities may complement under-five mortality studies in the use of targeted interventions and also judicious use of constraint budgetary resources.

Study Objectives

The main aim of this study was to investigate the effect of individual, household, community and spatial factors on neonatal mortality in the Kintampo Districts.

Specific Objectives

The specific objectives of the study were to:

1. analyse the risk of neonates dying within the first 28 days of life in the Kintampo Districts;
2. assess individual, household and community level factors associated with neonatal mortality in the Kintampo Districts;
3. analyse patterns of spatial clustering for all-cause neonatal mortality in the Kintampo Districts;
4. assess spatial clustering of cause-specific neonatal mortality in the Kintampo Districts.

Study Hypotheses

1. There is no statistically significant relationship between previous adverse pregnancy and neonatal mortality;
2. There is no statistically significant relationship between gravidity and neonatal mortality in the Kintampo Districts;
3. There is no statistically significant effect of household crowding on neonatal mortality in the Kintampo Districts;
4. Spatial clustering for cause-specific neonatal mortality is not statistically significant in the Kintampo Districts.

Significance of the Study

According to GDHS report (2014), risk of neonatal death in Ghana is twice that of post-neonatal death. Therefore, findings of this study will contribute to the understanding of high risk of neonatal death in Ghana. Moreso, study findings may reveal the situation pertaining to high rates of cause-specific neonatal deaths in some villages in the Kintampo Districts. In addition, the findings will shed more light on how maternal and household factors influence the risk of neonatal mortality. Findings from this study may also strengthen the already existing interventions by District Health Directorate and the District Assemblies in the quest to reduce risk of neonatal mortality. Moreover, these findings may be considered for targeted intervention for neonatal mortality in the districts by Health Directorates and impending programmes aimed at reducing incidence of neonatal mortality in the Districts. Furthermore, the findings may inform healthcare workers on postnatal activities that have to be strengthened within the communities of the districts. Additionally, the findings may generate hypotheses for further research by researchers in health research centres and academia. Finally, the findings will augment especially the already existing literature on factors affecting neonatal mortality.

Delimitation

This study was conducted in the Kintampo North Municipality and South District. The focus of the study was to investigate the influence of individual, household and community level factors on neonatal mortality in the Kintampo Districts. The spatial effect of communities on all-cause and cause-specific neonatal mortalities were also investigated. Finally, the risk of neonates dying within the first 28 days of life was analysed.

Definition of Terms

Neonatal mortality: This refers to the probability or risk of newborns dying within the first 28 days of life.

Neonatal cause-specific mortality: This refers to neonatal deaths which are attributable to a specific morbidity or complication.

Multi-level analysis: It is a type of analysis that involve data that are naturally hierarchical

Spatial: Relating to space.

Gravidity: Refers to the number of times a woman has been pregnant.

Organisation of the Study

The study is organised into nine chapters. Chapter one of this study presents the introduction which entails the background to the study, problem statement, aim and specific objectives, study hypotheses, significance and delimitation of the study. Chapter two focuses on a review of the literature related to the problem. The review includes sub-sections regarding the global burden of neonatal mortality, sub-Saharan Africa and Ghana. It also includes community level effect on neonatal mortality, household level effect on neonatal mortality, individual level effect on neonatal mortality, major risk factors of neonatal mortality and overview of spatial distribution studies on neonatal mortality in sub-Saharan Africa. In addition, chapter three includes theoretical consideration and conceptual framework that guided the study. The methodology and the procedures used to measure study variables have been presented in Chapter four. Statistical analyses and methodological procedures are presented in chapter five. The results of the analyses are presented in chapters six and seven. Results involving risk of neonatal death within the first 28 days as well as the effect of community, household and individual level factors on the risk of neonatal mortality are presented in chapter six. Results involving spatial clustering of neonatal cause-specific and all-cause mortalities are also presented in chapter seven. Discussion is presented in chapter eight whereas chapter nine embodies a summary, conclusion and recommendations.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction

This section focused on a review of literature related to the study. The section is organised into eight sub-sections namely global burden of neonatal mortality, neonatal mortality burden in sub-Saharan Africa, burden of neonatal mortality in Ghana, major risk factors associated with neonatal mortality, community level effect on neonatal mortality, household level effect on neonatal mortality, individual level effect on neonatal mortality and overview of spatial impact on neonatal mortality in sub-Saharan Africa.

A three-step search strategy was used to retrieve published articles related to neonatal mortality. Initial limited search of pubmed and scopus databases was undertaken. This was followed by analyses of text words contained in the title and abstract, and also the index terms used to describe the article. A second search was done by using all identified key words and index terms to search pubmrd and scopus databases. Thirdly, the reference list of all identified studies were searched for additional studies related to this work by using Google Scholar search engine, PDF Science meta-search engine and Carrot2 meta-search engine. Hand searches were also done across Google Scholar, PDF Science meta-search engine and Carrot2 meta-search engine to identify articles that focused on neonatal mortality.

Global Burden of Neonatal Mortality

The neonatal period is the most vulnerable stage in childhood survival and the need to accelerate progress in childhood survival makes the focus of newborn survival very crucial (UNICEF, 2014). Globally, neonatal mortality constitutes 45% of under-five mortality and 75% of neonatal deaths occurs in the first week of life (UNICEF, 2015).

Between 1990 and 2013, proportions of under-five mortality attributed to neonatal mortality increased in every region of the world (Wang et. al., 2014). Moreover, within a period of 43 years (1970-2013), the global proportions of neonatal deaths have increased progressively from 33% in 1970 to 37% in 1990 and then to 42% in 2013 (Wang et. al., 2014). Most of these neonatal deaths occurs in low- and middle-income countries with more than half of these deaths occurring at home where there is lack of drugs and limited healthcare professionals to assist in healthcare delivery (Lawn, Cousens & Zupan, 2005). Current available evidence has proven that too many babies die on their day of birth and first week of life. Globally, 1 million babies die on their day of birth and 2 million die weekly each year (UNICEF, 2015).

Five countries in the world together account for more than half (53%) of the world's neonatal deaths. These countries are India (27.8%), Nigeria (7.2%), Pakistan (6.9%), Democratic Republic of Congo (6.4%) and China (4.6%). (Liu, 2014) Neonatal mortality rates also range from 1.2 per 1000 in Singapore to 42.6 per 1000 in Mali (Wang et al., 2014). Because of these high burdens, the global progress was not enough to achieve the MDG 4 target of reducing under-five mortality (with neonatal mortality constituting the highest proportion) by two-thirds. Only two regions (East Asia and the Pacific and Latin America and the Carribean) and 62 countries were able to achieve the MDG 4 target (UNICEF, 2015). Fourteen million (14,000,000) lives could have been averted between 2000 and 2015 if all the countries in the world had met MDG 4 (UNICEF, 2015). In 2015, the neonatal mortality rates per 1000 live births were 9 for Central and Eastern Europe/Commonwealth of Independent States, 9 for Latin America and the Carribean, 9 for East Asia and the Pacific, 15 for Middle East and North Africa, 29 for sub-Saharan Africa and 30 for South Asia (You et. al, 2015). This is an indication that sub-Saharan Africa and South Asia are currently the major contributors of neonatal mortality in the world. According to a UNICEF report, the SDG target of reducing neonatal mortality rate to 12 per 1000 can be achieved if 63 countries in the world accelerated their progress (You et. al, 2015). It is therefore important to prioritise neonatal mortality especially in sub-Saharan Africa and South East Asia in order to achieve the SDG 3.2 (You, Hug, Chen, Newby, Wardlaw, 2014).

Newborn deaths can be prevented by using simple cost-effective and proven strategies (UNICEF, 2014) and despite the availability of these strategies, 2.8 million babies died largely from preventable causes in 2013 (UNICEF, 2014). In addition, many neonatal deaths could be avoided across the continuum of care but many women forgo this key intervention. One-third of newborns are delivered without the assistance of a skilled healthcare provider and this even compounds the burden of neonatal mortality worldwide. Besides, only about half of pregnant women receives the recommended minimum of four antenatal care visits globally. (UNICEF, 2014) All these factors contribute to the global burden of neonatal mortality.

Burden of Neonatal Mortality in sub-Saharan Africa

Sub-Saharan Africa constitutes about 11% of the global population but accounts for more than 25% of neonatal deaths (UNICEF, 2014). Globally, 20 countries have high risks of neonatal deaths but 75% of them are in sub-Saharan Africa (Lawn, Mongi & Cousens, 2011). In addition, 1 newborn out of 36 die every month in sub-Saharan Africa as compared with 1 out of 333 in the World's high-income countries (Hug et al., 2017). Meanwhile 800,000 of these deaths could have been averted if the established interventions that already formed part of policies were in place and being patronised by 90% of mothers and their newborns. The lives of 800,000 newborns could have been saved at an affordable cost of US $1.39 per capita. (Lawn Mongi & Cousens, 2011) What aggravates the burden is that more than half of all women in sub-Saharan Africa deliver at home without skilled attendants and two-thirds of women who need Emergency Obstetric and Newborn Care (EmONC) do not receive it (Lawn & Kerber, 2006).

Fifty percent of neonatal deaths in Africa occurs in just five countries namely Nigeria, DR Congo, Ethiopia, Tanzania and Uganda. Also, all these countries are in sub-Saharan Africa and this shows a huge burden of neonatal mortality in sub-Saharan Africa (Afolabi, 2017). In total, 88% of neonatal deaths in sub-Saharan Africa are attributed to infections (39%), complications from preterm birth (25%) and birth asphyxia (24%) (Afolabi, 2017). Causes of neonatal deaths in the sub-region are preventable and can easily be treated with proven cost-effective curable interventions (UNICEF, 2015) yet healthcare systems are weak. The major causes of neonatal deaths in sub-Saharan Africa are however not the factors that predispose neonates to deaths in developed countries. This means that these conditions are rare in developed countries and can also be treated promptly to avoid death if such conditions were seen. (UNICEF, 2014)

A couple of countries in Africa have similar neonatal mortality rates as those of advanced countries (Lawn, Mongi & Cousens, 2011). This corroborates the assertion that with concerted efforts many African countries can reduce neonatal deaths immensely (UNICEF, 2014). Moreover, minimizing social inequities in access to quality healthcare may reduce the burden of neonatal deaths in sub-Saharan Africa. For instance, even in the sub-Saharan Africa region, South Africa relatively has higher GNI (Gross National Income) per capita but her risk of neonatal death is twice that of three countries with the lowest risk of neonatal deaths in the region (Lawn, Mongi & Cousens, 2011).

Babies in sub-Saharan Africa are also at high risk of being born preterm (high risk for neonatal deaths) and regional estimate of preterm birth is 12%, which is twice that of Europe (Afolabi, 2017; Howson, C. P., Kinney, M. V., & Lawn, J. E., 2012; Wagura, Wasunna, Laving, Mawalma, Nganga, 2018). This high risk may be attributable to a myriad of factors such as malaria, sexually transmitted infections (STIs) and HIV/AIDS (Afolabi, 2016; Lawn, Mongi & Cousens, 2011). Moreso, many preterm births in Africa are low birthweight (LBW) which is another risk factor for neonatal death. Although Asia has twice the LBW rate as compared to Africa, majority of their LBW babies are term babies which are attributed to intra-uterine growth retardation. (Lawn, Mongi & Cousens, 2011) Hence, Africa needs to focus and intensify interventions that will reduce preterm births and also identify newborns with LBW and preterm status to provide them with the necessary support. One other problem that contributes to the burden of high risk of neonatal mortality in sub-Saharan Africa is the early neonatal deaths at home that are unseen and unaccounted for in official statistics to inform appropriate intervention strategies and policies (Lawn et al., 2004). In many communities of sub-Saharan Africa, babies are hidden until the sixth week when they are ready to be named. This tradition contributes to concealment of babies' death as mothers and family members often hide and conceal their mourning from the community. (Lawn, Mongi & Cousens, 2011)

Burden of Neonatal Mortality in Ghana

The burden of neonatal mortality in Ghana is increasing over time. Within the period 1998-2014, the proportion of neonatal mortality among infants increased from 53% to 71%. Within the same period, the proportion increased among under-five children from 28% to 48%. (GSS, GHS & ICFI, 2015). These figures show that neonatal mortality constitute a significant proportion of both infant and under-five mortality in Ghana. Findings from a study in Northern Ghana indicated that only 13% of neonatal deaths occurs in the hospital and 62% of mothers receives unskilled assisted delivery (Baiden et. al., 2006). Also, a study carried out in Ghana revealed that 20% of neonatal in-patient admissions resulted in deaths (Owusu, Lim, Makaje, Wobil, SameAe, 2018). According to 2017 Ghana Maternal Health

Survey report, 79% of women deliver at the health facility and 79% of women also receive skilled delivery but almost half (48%) of under-five deaths occurs in the neonatal period (GSS, GHS & ICFI, 2015).

Inspite of the efforts being made to reduce neonatal mortality by the implementation of Health Sector Medium-Term Development Plan 2010-2013 and Child Health Policy 2007-2015, neonatal mortality has since 2008 declined marginally as compared to post-neonatal and under-five mortalities. Between 2008 and 2014, neonatal mortality rates declined marginally by 3 percentage points as compared to post-neonatal and under-five mortality rates that declined significantly by 38 and 25 percentage points respectively. (GSS, GHS & ICFI, 2015) Besides these, neonatal mortality rate in Ghana is expected to be reduced by 17 percentage points before meeting the SDG 3.2 of reducing neonatal mortality to 12 per 1,000. Hence, multi-faceted interventions and strategies will have to be adopted to reduce neonatal mortality immensely. Providing effective interventions and strategies needs reliable and quality data but the national survey data alone will not be adequate. Civil event registers will be appropriate to support survey data but Ghana lacks fully functional civil registration system which is used to continually record births and deaths nationally (UNICEF Ghana Bulletin, 2015). It will therefore be appropriate to have Health and Demographic Surveillance Systems in defined areas across the country to supplement the national survey data as effort is being made to combat neonatal mortality in Ghana.

Neonatal mortality differs geographically in Ghana (GSS, GHS & ICF Macro. (ICFM), 2009; GSS, GHS & ICFI, 2015). Neonatal mortality rates are higher in the urban areas (33 deaths per 1000 live births) than rural areas (29 deaths per 1000 live births) as stated in the 2014 Ghana Demographic and Health Survey report. The incident rates are higher in the northern parts of the country than the southern parts (UNICEF Ghana Bulletin, 2015). This is attributable to the fact that the northern regions of Ghana have since time immemorial lagged behind the south in terms of healthcare services, infrastructure development, donor support, educational access and the political will (Streifel & Bliss, 2014). Paradoxically, neonates born to women who had secondary education or above have the highest rate (36 deaths per 1000 live births) of death in Ghana while neonates whose mothers had middle, JSS or JHS education have the lowest rate (28 deaths per 1000 births) of death (GSS, GHS & ICFI, 2015). Ironically, neonates born into households within the highest wealth quintile have the highest rate of death (40 deaths per 1000) as compared to neonates belonging to the second (26 deaths per 1000 live births) and middle (26 deaths per 1000 live births) household quintiles who have the lowest rates of death (GSS, GHS & ICFI, 2015).

Major risk Factors of Neonatal Mortality

Studies have identified several neonatal mortality risk factors (Edmond et al., 2008; Lawn, Cousens, & Zupan, 2005; Liu et al., 2012; Debelew et al., 2014; Welaga et al., 2013) but the major ones are neonatal infections, preterm birth, low birth weight, congenital anomaly, asphyxia and maternal intrapartum complications (complications during childbirth and labour) (Lawn, Cousens & Zupan, 2005; Liu, 2012; UNICEF, 2014). The neonatal infections mainly include, sepsis, pneumonia, tetanus, diarrhoea, meningitis and malaria (Rahman & Huq, 2009; UNICEF, 2015).

Globally, the majority of neonatal deaths are caused by preterm birth complications (35%), intrapartum complications (24%) and sepsis (15%) (United Nations, 2015). In sub-Saharan Africa, 88% of neonatal deaths are due to infections (sepsis, pneumonia, diarrhoea, meningitis and neonatal tetanus), asphyxia, and preterm birth complications (Lawn, Mongi & Cousens, 2011).

These major risk factors vary geographically and across time (Adjuik et al., 2010). Globally, 25% of neonatal deaths were caused by diarrhoea, tetanus, pneumonia and sepsis in 2012 (UNICEF, 2012). However, only 7% of these neonatal deaths were caused by four of these diseases in high-income countries as compared with 27% in sub-Saharan Africa (You, Hug, Chen, Newby, Wardlaw, 2014). In 2013, diarrhoea (1%) contributed to the least neonatal deaths whereas preterm birth complications (35%) contributed to the highest deaths. The rest of the neonatal deaths were attributable to tetanus (2%), pneumonia (5%), sepsis (15%) and intrapartum related complications (24%). (You, Hug, Chen, Newby, Wardlaw, 2014) These show that the cause-specific neonatal mortality differs by distribution and geographic location. Therefore, the preventive and intervention strategies will be effective depending on the distribution and geographic location of these major risk factors. Since the major risk factors vary across time, intrapartum related complications reduced globally to 11% in 2015. Moreover, diarrhoea related deaths increased to 8% whereas neonatal sepsis decreased to 7%. (You, Hug, Ejdemyr, Beise, Idele, 2015)

Ghana is among the first fifteen African countries with high risk of neonatal deaths (Lawn, Mongi & Cousens, 2011). In 2008, infections were the primary cause of neonatal mortality in Ghana (32%) followed by preterm birth complications (27%) and asphyxia (23%) respectively (GSS, GHS & ICFM, 2009). In 2014, data from Ministry of Health also showed that infections were the leading cause of neonatal deaths (31%) followed by preterm birth complications (27%) and intrapartum-related deaths (23%) respectively (Ministry of Health, Ghana, 2014). Welaga and colleagues (2013) found infections to constitute 32% of neonatal deaths; 21% from birth injury and asphyxia; and 18% from preterm births. This trend makes infections, asphyxia and preterm births complications form a high proportion of major causes of neonatal mortality in Ghana. In addition, it corroborates the claim that the proportions of cause-specific neonatal mortality varies with time, even in the same geographic location.

There are possible mechanisms that lead to infections in newborns. For instance, birth asphyxia in newborns occurs when the baby is not able to breathe spontaneously after delivery and it usually causes neonatal deaths during the first day of childbirth. About 70% of babies associated with high-risk pregnancies get asphyxia because of small body size, premature lungs and respiratory system and pulmonary and in-utero complications during the intrapartum period. Asphyxia leads to low oxygen (hypoxemia) and retention of carbon dioxide (hypercapnia) which results in death of the newborn where there is no rapid resuscitation. (Grady et al., 2017) Other neonatal infections such as sepsis is due to invasive bacterial infection; pneumonia is due to aspiration of infected amniotic fluid as a result of prolonged labour; meningitis results from bacterial infection of the meninges; and neonatal tetanus occurs as a result of neurotoxic bacteria found in the umbilicus of the neonates. All these infections are transmitted from the mother to the newborn during childbirth complications or shortly after childbirth. Preterm births are associated with many factors but clinical factors include vaginal bleeding or premature rupture of the amniotic membranes. (Lawn et al., 2008)

Community Level Factors Associated with Neonatal Mortality

Introduction

The causes of death during the neonatal and post-neonatal periods are mainly due to endogenous and exogenous factors (Lalou,1997). Endogenous causes are associated with genetic and biological factors leading to neonatal and child deaths (Tymicki, 2009). However, endogenous factors are strongly influenced by exogenous factors such as environmental, socio-economic and cultural factors (Tymicki, 2009; Vandresse, 2006). For this reason the community in which children find themselves influences their survival (Adedini et al, 2015; Kramer, Seguin, Lydon, Goulet, 2000; Van de Poel, 2009). Theory and studies have been able to demonstrate that differences in health outcomes of children residing in different communities can be linked to the communities in which they reside (Galster, 2010; Manda, 2001; Sastry, 1996). This section focused on the literature in other parts of the world, narrowed it to Ghana and then described the possible mechanism behind the causes of neonatal deaths. Many of the mechanisms that leads to neonatal deaths are similar to infant and under-five deaths so the literature review covered works with similar mechanism that have been done in the area of infants and under-five mortality. Moreover, the literature review on infants and childhood mortality was able to unearth studies which have been extensively undertaken in areas that are deficient in neonatal mortality.

Impact of Community Level Education on Neonatal Mortality

Formal education or high literacy level in the community has been found by a couple of studies to reducing neonatal mortality (Kayode et al., 2014). Studies regarding the influence of community education on infant and under-five mortality have also been undertaken (Boco, 2010; Kravdal, 2004; Sastry, 1996). In India for instance, Kravdal (2004) found communities where women have higher average duration of education to be associated with reduced risk of child mortality (Kravdal, 2004). Using datasets from 28 countries in sub-Saharan Africa including Ghana, Boco (2010) found that children in communities with high proportion of women having secondary education or higher had a less risk of mortality. In Ghana, Buor (2003) observed that relatively high proportion of educated people in a community produced the differential effect of child mortality between rural and urban areas.

Studies have found that community educational level effect largely operates through maternal healthcare utilisation (prenatal, postnatal care and family planning services), child nutrition and the ability or skill of the mother to take care of the sick child (Buli, 2013; Gabrysch & Campbell, 2009; Sharma, 1997).

Fotso and Kuate-Defo (2005), Pamuk et al. (2011), and Adekanmbi et al. (2011) were able to establish that community with high proportion of educated women had a positive impact on child survival. That notwithstanding, the higher community education in general also has a beneficial effect on neonatal and child mortality since highly educated husbands are more likely to foot healthcare bills and also have positive influence on their wives' pre- and post-natal care (Mosley & Chen, 1984; Fink, Gunther & Hill, 2010). In addition, women also learn good reproductive healthcare practices through societal network (Andrzejewski, Reed & White, 2009; Kohler, Behrman & Watkins, 2001). This is done through communication and imitation from other members of the community (Andrzejewski, Reed & White, 2009). This implies that even if the mother is an illiterate and resides in a community with high proportion of people with higher level of formal education, she is able to get better healthcare-related information from those who are highly educated and also imitate the common childcare practices that have been approved by members of the community (Andrzejewski, Reed & White, 2009; Kohler, Behrman & Watkins, 2001).

Kravdal (2004) and Boco (2010) found that even in communities where high proportion of women have higher level of education and probably low educational status of men, the mortality of children in the community decreases because of the same mechanisms. In addition, mothers with high level of education are able to understand and properly adhere to instructions and prescriptions given by clinicians as compared to mothers with low education (Buor, 2003; Kravdal, 2004; Rahman & Huq, 2009; Huda, Tahsina, Arifeen, Dibley, 2016; Vandresse, 2006). Besides, educated mothers are more abreast with information regarding modern technology in healthcare and as a result are able to defy strict negative cultural norms in their communities (Buor, 2003; Kravdal, 2004; Rahman & Huq, 2009; Huda, Tahsina, Arifeen, Dibley, 2016).

Highly educated women are also more likely to comply by the right prescription of contraceptive use, seek adequate vaccination for their children and also adhere to vaccination schedules (Buor, 2003; Bloom, Wypij, & Gupta, 2001; Kravdal, 2004; Rahman & Huq, 2009; Huda, Tahsina, Arifeen, Dibley, 2016). These mechanisms partly explain why children in communities that have a lot of educated women have a reduced risk of mortality. Besides these, highly educated women's decision-making, physical, economic and emotional autonomy are inversely associated with neonatal, infant and child mortality (Ganle, Otupiri, Parker, Fitzpatrick, 2015; Huda, Tahsina, Arifeen, Dibley, 2016; Kravdal, 2004). For instance, a woman who will be able to afford transportation and medical fees will not wait for her husband's financial assistance. She will rather seek prompt healthcare to prevent her child from dying. All but the latter autonomy (emotional autonomy) which refers to the closeness of the woman to her husband is not highly influenced by education. Closeness of relationship can not necessarily be fully dependent on the level of education. However, egalitarian relationship which reduces the risk of child death is highly influenced by higher level of women's education (Jejeebhoy, 1998).

There is a school of thought that people get attracted and migrate to communities with high proportion of educated people. This phenomenon opens up job opportunities in such communities and also influences government to provide them with quality infrastructure such as hospitals, good roads and sanitation facilities which help to improve child survival. (Kravdal, 2004).

However, there is a contrary view that higher education can have adverse effects on child survival (Gabrysch & Campbell, 2009). Women with higher education are likely to give birth at an advanced age and as a result, they give birth at short intervals with the aim of getting the required number of births (Gabrysch & Campbell, 2009). Since short birth intervals have a high risk on neonatal mortality, communities with high proportion of highly educated women may have negative impact on child, infant or neonatal survival. Highly educated women may not also have enough time to provide adequate nutrition for their newborn babies since the time allotted to their work may be competing with the time they have to spend with their babies (Reid, 2001).

Impact of Community Poverty Level on Neonatal Mortality

Relatively high proportion of poverty in communities has also increased risk of neonatal mortality (Kayode et al., 2014; Zanini, de Moraes, Giugliano, Riboldi, 2011). After having adjusted for contextual and compositional factors, Zanini and colleagues' (2011) study in Brazil revealed that 15% of neonatal mortality variation across 35 micro-regions in Brazil could be explained by poverty. Griffiths et al (2004) conducted a multi-level study which involved six sub-Saharan Africa countries including Ghana and four Indian states to assess the impact of household, community and regional effect on children's survival. The study found that differences in nutritional status between communities is explained by household socio-economic differences between communities (Griffiths, Madise, Whitworth, Matthews, 2004). Moreso, findings of a study conducted in the United

States of America showed that infant mortality differences between blacks and whites were partly attributable to blacks living in poor neigbourhoods (Strait, 2006). In addition, studies carried out in Nigeria (Adedini et al., 2015; Adekanmbi, Kayode & Uthman, 2011) and India (Singh, Kumar & Kumar, 2013) observed that neonatal, infant and child survival was affected adversely by poverty in the community. Titaley and co-investigators (2008) however, did not find any significant association between mean household wealth index of communities and neonatal mortality in their multi-level study after having controlled for socio-economic, proximate and other community covariates (Titaley, Dibley, Agho, Roberts, Hall, 2008). Studies involving the survival of children born to women in different areas of urban communities (Ahsan, Arifeen, Al-Mamun, Khan, Chakraborty, 2017), as well as lower survival in rural than the urban setting has been attributed to poverty (Fotso & Kuate-Defo, 2005; Sastry, 1997a).

There are limited studies of community poverty and child survival in Ghana. However, a multi-level analysis study carried out by Kayode and team of investigators (2014) in Ghana showed community poverty to be partly associated with increased risk of neonatal mortality.

High proportion of poverty in a community means most parents are illiterates or have lower levels of education (Gopalan, 2000). Therefore, any risk of neonatal or child mortality such as low attendance of pre- and post-natal care, poor environmental sanitary condition and lack of skills to take good care of the child et cetera, that are associated with lower education level are also associated with community poverty (Huda, Tahsina, Arifeen, Dibley, 2016). Moreover, high level of community poverty will result in lack of learning good child healthcare practices through social networks that are associated with community having large proportion of people with higher education (Andrzejewski, Reed & White, 2009). In line with literature, wealthy parents or families are able to purchase goods and services required to meet the child's basic needs (Gordon et al., 2003). Hence, larger proportion of wealthy parents in a community improves chances of child survival. High proportion of poverty in the community has the consequences of many pregnant women being underfed. This predisposes pregnant women to a higher risk of preterm birth which subsequently reduces babies' chances of survival (WHO, 2012).

Influence of Unimproved Water and Sanitation at the Community Level

A body of the literature also finds lack of improved community-level water and sanitation to be associated with high risk of neonatal mortality (Grady et. al., 2017; WHO, 2012; Zanini, de Moraes, Giugliano, Riboldi, 2011). Although the lack of improved water and sanitation has negative impact on child mortality, their (water and sanitation) relationship with neonatal mortality is not clear (Ezeh, Agho, Dibley, Hall, Page, 2014; Kamal, 2012; Rahman & Abidin, 2010). Some studies have shown the negative impact of unimproved water and sanitation on neonatal and child survival in the household environment (Ezeh, Agho, Dibley, Hall, Page, 2014; Fuller, Villamor, Cevallos, Trostle, Eisenburg, 2016; Harris, Alzua, Osbert, Pickering, 2017; Singh et al., 2013). However, controlling for the effect of community-level sanitation in a number of studies nullified the association between household sanitation and childhood or neonatal survival (Barreto et al., 2007;

Buttenheim, 2008; Fuller, Villamor, Cevallos, Trostle, Eisenberg, 2016; Harris, Alzua, Osbert, Pickering, 2017). In effect, there is a stronger significant impact of community sanitation on childhood mortality as compared with household level sanitation (Gunther & Fink, 2010). Evidence from available data has shown that household practising proper sanitation and hygiene prevents the transmission of enteric pathogens to household nearby (Fuller, Villamor, Cevallos, Trostle, Eisenberg, 2016; VanDerslice, Popkin, Briscoe, 1994). Hence with at least a threshold proportion of households in communities engaged in proper sanitation, the rest which do not even have improved sanitation are protected from enteric diseases (Gunther & Fink, 2010; Fuller, Villamor, Cevallos, Trostle, Eisenberg, 2016; Harris, Alzua, Osbert, Pickering, 2017).

Harris and colleagues argued that households without improved sanitation or improper disposal of human excreta are likely to have a high risk of fecally contaminated water which can be catastrophic for the newborn who does not have a fully developed immune system (Harris, Alzua, Osbert, Pickering, 2017). This suggests that household water and sanitation need to be considered in studies that consider community-level sanitation coverage. However, the study of 128 villages in Mali, revealed that the quality of household stored water is associated with community sanitation coverage (Harris, Alzua, Osbert, Pickering, 2017). It is therefore prudent to consider only community sanitation coverage and water safety when conducting studies that involve communities and households. Fuller et al. (2016) conclude from their findings that household sanitation access is less important (Fuller, Villamor, Cevallos, Trostle, Eisenberg, 2016). Findings from several other studies were in line with Fuller et al. finding that, the effect of community sanitation coverage on child survival was significant after controlling for household sanitation and other factors (Alderman, Hentschel & Sabates, 2003; Andres, Briceno, Chase, Echenique, 2014; Barreto et al., 2007; Buttenheim, 2008; Corsi et al., 2011). In a meta-analysis involving 301 Demographic and Health Surveys and Multiple Indicator Cluster Surveys, Larsen and colleagues were able to demonstrate that higher community sanitation access irrespective of households' type of toilet facilities even had a higher beneficial effect on childhood survival (Larsen, Grisham, Slawsky, Narine, 2017). Time taken or total distance travelled to the source of drinking water and back also serves as a proxy for availability of water and hygienic conditions in the household (Nygren et al., 2016). It is assumed that the longer the distance travelled or time taken, the smaller the quantity of water in the household and consequently poor hygienic condition in the household. Thirty minutes or more for a round trip to the source of drinking water and back is considered to be a long duration (GSS, GHS & ICFI, 2015; United Nations, 2014).

Unimproved sanitation and water have several pathways through which neonates or children are predisposed to morbidity and mortality (Grady et al., 2017; Gunther & Fink, 2010; Fuller, Villamor, Cevallos, Trostle, Eisenberg, 2016; Oswald et al., 2017; VanDerslice, Popkin, Briscoe, 1994). Communities which are composed of high proportion of households with poor sanitation and hygiene have high risk of faecal water contamination in the households (Harris, Alzua, Osbert, Pickering, 2017). Consequently, children in those households who are not fully breastfed have a high risk of getting infected with intestinal diseases such as diarrhoea, cholera etc. through the drinking of liquid supplements and the infected water that contains enteric pathogens (Belachew, Kahsay & Abebe, 2016; Grady et al., 2017; VanDerslice, Popkin, Briscoe, 1994). The other pathway is children who come into contact with infected soil contract diseases (Oswald et al., 2017). Although it is not likely that newborns may come into contact with soil, available evidence suggests that prelacteal feeding (giving any food to a newborn within three days of birth) is a cultural practice that is prevalent in many developing countries (Belachew, Kahsay & Abebe, 2016; Degefie, Amare & Mulligan, 2014). In a study carried out in Ethiopia, 29% of the children were found to be prelacteally fed (Belachew, Kahsay & Abebe, 2016). The other mechanism or pathway is pregnant women exposed to unimproved water and sanitation might lead to transmission of infectious diseases (Grady et al., 2017).

This has a tendency of resulting in preterm birth which ultimately has a high risk of neonatal mortality (Howson, Kinney & Lawn, 2012). Grady et al. (2017) upon studying 131 districts (clusters) in 14 countries including Ghana contended that neonatal mortality differentials were due to water shortage or exposure of newborns to unimproved water sources during or immediately after home delivery. They further argued that newborns who are delivered in the communities (often the home) are likely to have intestinal or cord infections if the umbilical cord is not cleaned by improved water and/or the newborn is fed with watery-based diet (prelacteal feeding) instead of breastmilk (Grady et al., 2017). This suggests that improper cleaning of umbilical cord is also another pathway which may lead to neonatal deaths.

Impact of Ethnic Fractionalisation on Neonatal Mortality

The high concentration of ethnic groups in a particular area influences neonatal mortality (Adongo et al.; 1997; Brockerhoff & Hewett, 2000; Degefie, Amare, Mulligan, 2014; Gyimah, 2002a; Gyimah, 2002b; Sutan, 2014). Ethnicity may have positive or negative impact on neonatal survival depending on whether a specific ethnic group is engaged in positive or negative norms, beliefs, traditional or cultural practices involving the newborns health. Available evidence shows that a highly homogeneous ethnic community improves the survival of newborns since they are more likely to do business among themselves to improve their socio-economic status and ultimately improve the survival of their babies (Brockerhoff & Hewitt, 2000). Moreover, in such an environment if the predominant ethnic group is dominant in a national political economy, there are likely consequences of improvement in the socio-economic status of their members and lives of their newborns and children (Brockerhoff & Hewitt, 2000; Posner, 2004). On the contrary, a highly heterogeneous (or fractionalised) society has a high potential of leading to ethnic conflict which has a devastating effect on mothers and their babies (Annett, 2001; Fearon, 2003).

In a study carried out in United States of America, Cramer et al. found that infants born to mothers who were school dropouts had a 50% increased risk of death as compared to infants born to college graduates among Anglos and Blacks (Cramer, 1987). However, among the Hispanics there was marginal effect of educational level on the risk of infants' deaths. Cramer (1987) argued that there is a rich culture and tradition among all Hispanics irrespective of their educational level and that explains this phenomenon. Hence, the ethnic (or racial) differences in culture and tradition explains this phenomenon. In Ghana for instance, the Kassena-Nankana ethnic group have a misconception about contraception that reduces fertility but they, however, have a rich culture that promotes prolonged spousal separation and lactational amenorrhoea. This particular culture reduces short preceding birth intervals which pose a high risk for neonatal survival (Adongo et al., 1997). Besides, the Acehnese people in Indonesia have a culture of warming themselves and their newborn babies by sitting near fire, a practice known in their local parlance as "didaring". Due to this practice, neonates are given warmth and this ultimately reduces neonatal mortality among mothers belonging to groups where this practice is predominant (Sutan & Berkat, 2014). It therefore suggests that communities with highly concentrated ethnic groups with rich health-related culture are likely to have a reduced risk of neonatal mortality.

Negative cultural practices or beliefs of a specific ethnic group who dominate in communities are likely to have adverse effects on neonatal survival (Adongo; 1997; Gyimah, 2002b; Degefie, Amare & Mulligan, 2014; Ganle, Otupiri, Parker, Fitzpatrick, 2015). Women of particular ethnic groups in Ethiopia discard the nutritious colostrum before initiating breastfeeding because they perceive it to be dirty and therefore not good for the baby (Degefie, Amare & Mulligan, 2014). In addition, they have a belief that the placenta is a "blanket" for the newborn and any harm caused to the placenta has negative consequences on the newborn's health. For this reason, when a baby is delivered, the attendants focus on the mothers' health and how to successfully discard the placenta without even covering the baby with a cloth (Degefie, Amare & Mulligan, 2014). Furthermore, breastfeeding is sub-optimal among these ethnic groups in the communities because they give a herbal concoction ("hamesa") to the baby with the belief that it will protect them from illness of all kinds (Degefie, Amare & Mulligan, 2014).

In Ghana, there are negative beliefs, rituals, traditions and culture related to pregnancies and childbirth (Adongo et al., 1997; Gyimah, 2002b). Gyimah's (2002a) study in Ghana suggested that birth spacing is influenced intrinsically by ethnic practices as well as socio-economic and demographic factors. Gyimah later carried out a study which revealed that intrinsic ethnic norms are weakly associated with infant mortality while the socio-economic status of mothers have a strong inverse relationship with infant mortality (Gyimah, 2002b). Though in both studies the bivariate analyses showed a strong influence of ethnicity on infant mortality and birth spacing, the effect of ethnicity was attenuated when socio-economic factors were controlled for. Since interactions are appropriate for showing pathways which are important for targeted interventions (Sastry, 1996; Shell-Duncan & Obiero, 2000), it would have been appropriate for the two studies to assess interactions between socio-economic status and ethnicity on infant mortality and birth spacing. Available evidence also shows that some ethnic specific practices in Ghana also deprive newborns of the rich nutrient colostrum. Certain groups are of the belief that: (a) the yellowish colostrum is dirty and it is bad for newborns; (b) its consumption by newborns will make their heads ugly (Gyimah, 2002b). Moreover, among the Akan ethnic group in Ghana convulsion is attributed to evil spirits, hence the first point of call for many Akans is the traditional healer to exorcise the evil spirit before visiting the health facility if there is the need to do so (Gyimah, 2002b). Also, among the Kassena-Nakana ethnic group, some children once identified by the soothsayers as "spirit children" are killed. This is because they are of the belief that "spirit children" can destroy their families and their communities and are therefore not meant to live in this world (Adongo, 1997). In a nutshell, communities with high proportion of specific ethnic groups with negative cultural practices are likely to have a high risk of neonatal mortality.

Distance to the Nearest Health Facility and its Impact on Neonatal Mortality

Another community level factor that is crucial to neonatal mortality is the magnitude of the nearest distance to the healthcare facility or emergency obstetric and neonatal care (EmONC) facility (Karra, Fink & Canning, 2016; Malqvist, Sohel, Do, Eriksson, Persson, 2010; Mckinnon, Harper, Kaufman, Abdullah, 2014; Okwaraji, Cousens, Berhane, Mulholland, Edmond, 2012). This implies that the larger the nearest distance or time taken to reach the health facility, the more difficult it becomes for women to have access to the facility. This effect is more dominant in rural areas which have poor roads and weak transportation systems (Mckinnon, Harper, Kaufman, Abdullah, 2014). The lack of skilled care delivery and enabling environment for childbirth put mothers and their newborns' lives at risk of death. This is due to the fact that delivery assisted by a skilled healthcare professional in a health facility has a direct bearing on the prevention of infections, asphyxia and birth trauma (WHO, 2010). Moreover, as complications during labour requires prompt attention, delivering in a health facility will surmount the issue of delay in attending to these emergencies (Mckinnon, Harper, Kaufman, Abdullah, 2014). Hence, the lack of easy access to healthcare facility reduces the chances of neonatal survival.

The evidence available from several studies show that larger distances from mothers' homes or their village centroids to health facilities (or EmONC) increase the risk of neonatal, infant and child mortality (Karra, Fink & Canning, 2016; Kashima et al., 2012; Malqvist, Sohel, Do, Eriksson, Persson, 2010; Mckinnon, Harper, Kaufman, Abdullah, 2014; Okwaraji, Cousens, Berhane, Mulholland, Edmond, 2012). In a study conducted in Vietnam, Malqvist and colleagues (2010) demonstrated that neonates born to mothers who were living farthest away (between 4th and 5th distance quintile) from a health facility had almost double the risk of mortality as compared with neonates of mothers who were living closest (between 1^{st} and 3^{rd} distance quintiles) after having controlled for potential confounders. Kashima et al. (2012) study in Madagascar revealed that the risk of neonatal and infant mortality increased among mothers living farther away from a health centre after adjusting for other covariates. However, this effect was not significant. This study also showed that maternal health status, household wealth status and educational level which have effect on neonatal and infant mortality did not modify the effect of distance (Kashima et al., 2012). A study conducted in rural Ethiopia that found a strong positive correlation between travel time and distance to a health facility also found no interaction between travel time and household wealth (Okwaraji, Cousens, Berhane, Mulholland, Edmond, 2012). In addition, this study found that children under-five years whose mothers spent at least one and half hours (1.5-<2.5 hours, 2.5-<3.5 hours and 3.5-6.5 hours travel time) walking travel time to the nearest health facility had between 2 and 3 fold risk of death as compared to children living within a walking travel time of less than one and half hours (<1.5 hours) (Okwaraji, Cousens, Berhane, Mulholland, Edmond, 2012). Karra et al. (2016) also pooled the results of 29 Demographic and Health Surveys from 21 low and middle-income countries to estimate the combined effect of health facility distance on under-five mortality. Their findings concluded that neonates living within 2 km, 3 km and 5 km were 7.7%, 16.3% and 25% higher risk of mortality as compared with neonates within 1 km. The authors of this study emphasised the relatively small differences in distance from health facilities that resulted in substantial differences in neonatal mortality. Children (under five years) living farther than 10 km from a health facility were also found in this study to have a 26.6% higher risk of death as compared to children within 1 km (Karra, Fink & Canning, 2016).

Findings of studies in Ghana and other low and middle income countries have demonstrated that nearest distance to a health facility influences mothers' choices to deliver at health facilities (Gabrysch, Cousens, Cox, Campbell, 2011; Gething et al., 2012; Johnson et al., 2015; Kumar, Dansereau & Murray, 2014; Masters et al., 2013; Nesbitt et al,, 2016). Since the more mothers deliver in a health facility the more the risk of neonatal mortality reduces, communities with a high proportion of mothers closer to a health facility are likely to reduce the risk of neonatal mortality in that community. Despite that the Karra et al. (2016) were able to demonstrate that higher risk of neonatal deaths was associated with larger health facility distance, the same study also found that women farther than 10 km away from a health facility were 55.3% less likely to deliver in a health facility as compared to women within 1 km. In rural Zambia, Gabrysch et al. (2011) found that the likelihood of in-facility delivery was 29% lower as the health facility distance doubled.

Health facility distance has been shown to be strongly associated with in-facility delivery in Ghana (Gething et al., 2012; Johnson et al, 2015; Masters et al., 2013; Nesbitt et al., 2016). In Ghana, Gething and co-investigators (2012) triangulated detailed spatial data on population, health facilities and topographical features (such as rivers, mountains etc) that influences journey to estimate journey-time of all women of childbearing age to their nearest health facility. About a third (34%) of the women were found to live at places which will require more than two hours (two hours was considered as clinically significant threshold time) to access EmONC (Gething et al., 2012). This has a serious implication of reduced in-facility delivery and ultimately high risk of neonatal and maternal mortality. Masters et al. (2013) in using demographic and health survey data found that travel time had significant influence on in-facility delivery in rural Ghana after having adjusted for household wealth, educational level, female autonomy, facility capacity and season of birth. Furthermore, results from available data on rural areas in seven contiguous districts in Brong Ahafo region showed that compared to women who lived within 1 km (<1 km), those living between 1 km and 5 km (1-5 km) and farther than 10 km (>10 km) had 68% and 90% lower odds of delivering in a nearest health facility respectively (Nesbitt et al., 2016). In Nesbitt et al. (2016) study, the health facility distance was measured using the village centroids as a proxy for the women. It will, therefore, be appropriate to conduct a study in the area using the actual location of women's households to assess the findings. Lambon-Quayefio and Owoo (2017) found nearest distance to the health facility as an important predictor of neonatal mortality in Ghana. Apart from Lambon-Quayefio and Owoo (2017), many of the quantitative studies in Ghana assessed the relationship between in-facility delivery and health facility distance. Hence, there is the need to conduct more investigation on health facility distance and its direct impact on neonatal mortality in Ghana to advance the literature in this area.

Household Level Factors Associated with Neonatal Mortality

Household conditions indicate the standard of living in the household (Gopalan, 2000) and therefore have effects on neonatal outcomes. There are several household factors that are associated with neonatal mortality but this section focused on only the factors that were considered in this study (household wealth and crowding).

Impact of Household Wealth on Neonatal Mortality

Household wealth has been shown by many studies to have impact on neonatal and child survival (Kumar, Singh, Rai, Singh, 2013; Huda, Tahsina, Arifeen, Dibley, 2016; Rahman & Abidin, 2010). The impact of household wealth on neonatal and childhood survival is indirect since it operates through other factors to exert impact. For instance, children from poor households relatively have reduced chances of survival because these households are more likely to have poor housing quality, unsafe drinking water, poor sanitation and inability to access quality healthcare which have direct impact on the health outcomes of the children (Huda, Tahsina, Arifeen, Dibley, 2016). Studies conducted in Nigeria, Sudan, Yemen, India, Pakistan and Bangladesh have concluded that children from poor households (or households with low socio-economic status) as compared with those from rich households (or households with higher socio-economic status) have higher risk of neonatal, infant and child mortality (Alosaimi, Luoto, Serouri, Nwaru, Mouniri, 2015; Bashir, Ibrahim, Bashier, Adam, 2013; Ezeh, Agho, Dibley, Hall, Page, 2014; Kumar, Singh, Rai, Singh, 2013; Paudel, Thapa, Shedain, Paudel, 2013; Huda, Tahsina, Arifeen, Dibley, 2016). The effect of household wealth on health outcomes is bi-directional (Huda, Tahsina, Arifeen, Dibley, 2015). For instance, childhood ill-health in the household may result in poverty due to out-of-pocket expenditure on healthcare and drugs cost. In order to investigate whether household poverty results in neonatal mortality requires longitudinal data for which the systematic sequence that leads to neonatal mortality can be investigated. The study of the effect of household wealth on neonatal and child mortality in some developing countries such as Ethiopia, Kenya, Bangladesh, India and Indonesia did not however show any significant effect after having controlled for potential confounders (Titaley, Dibley, Agho, Roberts, Hall, 2008; Singh, Kumar & Kumar, 2013; Mekonnen, Tensou; Telake, Degefie,Bekele, 2013; Omariba, Beaujot, & Rajulton, 2007; Rahman & Abidin, 2010).

The basic determinants of childhood morbidities and mortalities are socio-economic statuses of the community and households since the root cause of the more proximate factors associated with poverty are lack of proper education, access to quality healthcare and nutrition, quality housing and poor environmental conditions (Fotso & Kuate-Defo, 2005; Sastry, 1996).

The pattern of the effect of household wealth on neonatal mortality in Ghana is generally not clear. In the Ghana Demographic and Health Survey report (2014), those in the highest wealth quintile had the highest neonatal mortality rate as compared with the rest (GSS, GHS & ICFI, 2015). For Welaga et al. (2013), neonates in the richest households had the highest risk of death in the unadjusted model though not significant. The effect of household wealth became insignificant when other covariates were adjusted for. Welaga and colleagues (2013) posited that the pattern observed may be due to the improvement of healthcare services in the study area. In a multilevel study carried out by Kayode and his team of investigators (2014) in Ghana, neonates in the richest households also had the highest risk of mortality after adjusting for potential confounders. However, this effect was not statistically significant.

Impact of Household Crowding on Neonatal Mortality

Household crowding (or overcrowding) has a direct impact on neonatal and child health outcomes (Aaby, 1987; Macassa, Ghilagaber, Benrhardt, Burston, 2004; Rahman, Rahman, Wojtyniak, 1985; Vajpayee & Govilla, 1987). This is because a large number of household members sleeping in a relatively small room promotes the rapid spread of infectious diseases, especially among children (Aaby, 1987; Vajpayee & Govilla, 1987). Studies have found early exposure to measles and respiratory infections because of household crowding (Macassa, Ghilagaber, Benrhardt, Burstrom, 2004; Rahman, Rahman, Wojtyniak, 1985). Household crowding also enhances the spread of diarrhoeal and other intestinal diseases (Woldemicael, 2000). Findings of a study carried out by Vajpayee and Govilla (1987) in rural India found families of large sizes congested in living rooms to have a higher risk of neonatal mortality. Aaby (1987) contended in his study conducted in Guinea Bissau that the higher case fatality rate of measles found among secondary cases is due to household crowding. The mechanism of rapid spreading of infectious diseases among crowded households is explained by the spread of pathogens directly from one household member to another (Woldemicael, 2000). In Ghana, no study of household crowding and its effect on childhood or neonatal mortality was readily available.

Individual Level Factors Associated with Neonatal Mortality

Introduction

This section touched on individual-level factors that influence neonatal and child mortality. The factors considered were based on theories and literature. Basically, maternal and neonatal factors that have effects on neonatal mortality were considered. Maternal factors that were considered in this study were maternal educational level, age, gravidity, previous adverse pregnancies (stillbirth, miscarriage or ectopic), place of delivery and tetanus toxoid vaccine status. The study focused on the following neonatal factors: sex, birth order and gestational age.

Influence of Maternal Educational Level on Neonatal Mortality

Several studies that examined maternal education on neonatal mortality found an inverse relationship between maternal education and neonatal mortality (Huda, Tahsina, Arifeen, Dibley, 2016; Kamal, 2012; Mekonnen, Tensou; Telake, Degefie, Bekele, 2013; Singh, Kumar & Kumar, 2013). Studies carried out on under-five and infant survival also support this finding. Outlining findings of studies in chronology, a study in Nigeria found an inverse relationship between under-five survival and maternal education (Adekanmbi, Kayode & Uthman, 2011). This was followed by studies conducted in Ethiopia, Bangladesh, India and Nepal that found a higher educational level of mothers to reduce the risk of neonatal mortality (Ayele, Zewotir & Mwambim, 2017; Kamal, 2012; Mekonnen, Tensou; Telake, Degefie, Bekele, 2013; Paudel, Thapa, Shedain, Paudel, 2013; Singh, Kumar & Kumar, 2013; Huda, Tahsina, Arifeen, Dibley, 2016). Conversely, this inverse relationship was not significant as other factors were controlled for in a couple of studies that sought to examine the effect of maternal education on neonatal and infant mortality (Akinyemi, Bamgboye & Ayeni, 2015; Ntenda, Chuang, Tirunah, Chuang, 2014; Zanini, Moraes, Giugliani, Riboldi, 2011). Few studies that examined the relationship between maternal education and neonatal mortality in Ghana, did not find any association (Engmann et al., 2012; Welaga et al., 2013; Kayode et al., 2014).

The pathway for impact of maternal education on neonatal mortality is explained by the fact that women with high education are more likely to: access prenatal care; deliver in a healthcare facility; afford quality healthcare; be knowledgeable and skillful in child healthcare; having prompt vaccination for their children; defying taboos and negative cultural practices; and having access to portable water and better sanitation facilities (Buor 2003; Kravdal, 2004).

Influence of Maternal Age at Delivery on Neonatal Mortality

Findings from available studies indicate that maternal age at delivery also influences neonatal mortality (Huda, Tahsina, Arifeen, Dibley, 2016; Kamal, 2012; Mekonnen, Tensou; Telake, Degefie Bekele, 2013; Singh, Kumar & Kumar, 2013). The prime age for women to deliver is between 20 and 34 years of age (Cunnington, 2001; Heffner, 2004; Klein, 2005; Utting & Bewley, 2011). The relationship between maternal age of delivery and neonatal and child mortality has been shown to be U-shaped; neonatal and child mortality increases for neonates and children whose mothers are below age 20 and above 34 years (Gyimah, 2002b). However, studies with maternal age categories which did not consider the specific age category 20-34 years, were able to demonstrate that younger and older maternal ages were still risk factors for neonatal mortality (Mekonnen, Tensou; Telake, Degefie, Bekele, 2013; Singh, Kumar & Kumar, 2013). Omariba and colleagues (2007) examined the determinants of infant and child mortality in Kenya by controlling for frailty and other potential effects. The findings of the study showed that infants and children of mothers with ages less than 20 years and greater than 34 years had an increased risk of mortality as compared to infants and children of mothers with ages between 20 and 34 years of age (Omariba, Beaujot, & Rajulton, 2007). Though the risk of infants of mothers older than 34 years was 14% higher in the study, it was not statistically significant. Kamal (2015) and Singh et al. (2012)

studies in Bangladesh and India respectively noted neonates of younger mothers to have higher risk of death. In sub-Saharan Africa, Bashir et al. (2013) study in Sudan, Mekonnen et al.'s (2013) study in Ethiopa, Ntenda et al.'s (2014) study in Malawi, Adedini et al.'s (2015) study in Nigeria established that relatively younger and older maternal ages increase the risk of neonatal, infant and child mortality. On the contrary, Titaley et al. (2008), Nisar et al. (2014) and Debelew et al. (2014) studies in Indonesia, Pakistan and Ethiopia respectively, did not show any effect of maternal age on neonatal mortality after other important factors were controlled for.

Ghana Demographic and Health Survey report in 2014 indicates that the influence of maternal age on child mortality in Ghana is generally U-shaped. The report further argued that risk of neonatal, infant and child death was generally higher among mothers under 20 years of age and more than 30 years as compared with mothers in the 20-29 years age bracket. This effect of younger and older maternal age on neonatal mortality was corroborated in the Welaga et al. (2013) and Engmann et al.'s (2012) studies in their univariate analysis but the effect was nullified when potential confounders were adjusted in the multivariate model.

Available evidence shows that children born to very young mothers have high risk of death because of the combined effect of physiological immaturity, social and psychological stress that are associated with it (Gyimah, 2002b; Tymicki, 2009). Studies have also hypothesised that competition between young mothers and foetuses for nutrients leads to high risk of death among neonates born to these mothers (Gyimah, 2002b; Kozuki et al., 2013; Tymicki, 2009). On the other hand, older mothers tend to give births repeatedly and at close intervals. This deprives them of the nutrient necessary for the index foetus leading to preterm birth which is associated with high risk of newborn's death (Gyimah, 2002b; Kozuki et al, 2013; Tymicki, 2009). They also have high risk of complications during births (Gyimah, 2002b; Kozuki et al, 2013; Tymicki, 2009). The afore-mentioned reasons are the probable mechanism that predisposes neonates born to younger and older women to high risk of death.

Impact of Tetanus Toxoid Vaccine on Neonatal Mortality

Neonatal tetanus is a severe bacterial infection caused by clostridium tetani (Roper, Vandelaer & Gasse, 2007). The case-fatality of neonatal tetanus is high in developing countries and it is usually attributed to unhygienic practices during birth and the early neonatal period (Roper, Vandelaer, Gasse, 2007; Grady et al., 2017). Tetanus toxoid vaccine has been shown to be effective against the reduction in risk attributed to neonatal mortality (Blencowe, Lawn, Vandelaer; Roper, Cousens, 2010; Mekonnen, Tensou; Telake, Degefie, Bekele, 2013; Singh, Pallikadavath, Ogollah, Stones, 2012; Singh, Kumar & Kumar, 2013). In a study carried out in Ethiopia, neonates of mothers who received two or more tetanus toxoid injections in comparison with neonates whose mothers received none or one tetanus toxoid injection during pregnancy had less risk of death (Mekonnen, Tensou; Telake, Degefie, Bekele, 2013). Besides, a study conducted in India showed that the risk of death was less for neonates whose mothers received one tetanus toxoid injection and also for neonates whose mothers received two or more tetanus toxoid injection. However, the protective effect for neonates whose mothers received two or more tetanus toxoid injections was higher than that of neonates whose mothers received only one tetatus toxoid injection (Singh, Pallikadavath, Ogollah, Stones, 2012). In Sudan, a study carried out was able to demonstrate that neonates of mothers who received at least one dose of tetanus toxoid vaccine had lower risk of death as compared to neonates born to mothers who received no dose of tetanus toxoid vaccine (Taha, Gray, Abdelwahab, 1993). In addition, Singh et al.'s (2013) study conducted in India showed that two or more doses of tetanus toxoid vaccine had reduced risk of neonatal death in comparison with none or one dose of the vaccine. Moreso findings from studies in Ethiopia (Kolola, Ekubay, Tesfa, Morka, 2016) and Bangladesh (Abir et al., 2017) revealed that giving pregnant women two or more doses of tetanus toxoid vaccine reduces the risk of neonatal mortality more than giving them one dose or none of the vaccine. These findings suggest that administering at least one dose of tetanus toxoid vaccine to pregnant women reduces the risk of neonatal mortality better than giving no dose of the tetanus toxoid vaccine to them (pregnant women). In line with these findings, a systematic review conducted by Blencowe et al. (2010) revealed that giving at least two doses of tetanus toxoid injections to pregnant women or women of childbearing age reduces the case-fatality risk among neonates substantially. However, a study carried out in Sudan did not show any impact of tetanus toxoid vaccine on neonatal mortality (Bashir, Ibrahim, Bashier, Adam, 2013).

Based on current literature, studies undertaken in Ghana described neonatal deaths attributed to tetanus rather than the protective effect of tetanus toxoid on neonatal mortality (Abdul-Mumin, Gumanga, 2016; Kyu et al., 2017). This is a research gap in Ghana which requires a well-conducted study in Ghana.

Neonatal tetanus is an acute disease that presents itself initially with the baby's inability to suck and then progresses with muscle rigidity and painful muscle spasms (Roper, Vandelaer, Gasse, 2007). The disease is caused by tetanus toxins that are produced by clostridium tetani (Roper, Vandelaer, Gasse, 2007). The tetanus spores' common point of entry is the unhealed umbilical cord. The tetanus toxoid vaccine received by the mother produces tetanus antitoxin which is transported through the placenta to the fetus which ultimately gives the newborn passive protection against tetanus during the neonatal period (Roper, Vandelaer, Gasse, 2007).

Influence of Maternal Place of Birth on Neonatal Mortality

Place of child delivery by the mother is found in the available literature to influence neonatal mortality (Ajaari, Masanja, Weiner, Abokyi, Owusu-Agyei, 2012; Moyer, Dako-Gyekye & Adanu, 2013; Nathan & Mwanyangala, 2012; Tura, Fantahun, Worku, 2013). Several factors such as maternal education, socio-economic status, attitude of health workers, cultural, severe complications during birth, previous complications during childbirth, distance to health facility and poor weak transportation systems have been found to influence mothers' decision on their place of delivery (Moyer, Dako-Gyekye & Adanu, 2013; Kitui, Lewis & Davey, 2013; Thaddeus & Maine, 1994). In Tanzania, a population-based study concluded that neonates born to mothers who deliver outside health facilities have a higher risk of mortality (Ajaari, Masanja, Weiner, Abokyi, Owusu-Agyei, 2012).

The authors further argued that women who deliver outside health facilities may be attended to by home delivery attendants but the attendants wait till there are complications before referring them to the health facility (Ajaari, Masanja, Weiner, Abokyi, Owusu-Agyei, 2012). Since referrals are most of the time not prompt, it becomes too late for health practitioners to save the lives of these babies and sometimes the mothers (Thaddeus & Maine, 1994,). Moyer et al.'s (2013) study analysed the relationship between rates of health facility deliveries and early neonatal mortality in a literature review involving 70 peer reviewed papers from 18 countries in sub-Saharan Africa that includes Ghana. The authors found that there were significantly lower rates of deaths among neonates born to mothers with higher delivery rates at the health facility (Moyer, Dako-Gyekye & Adanu, 2013).

A study conducted in Bangladesh also corroborated the finding of home delivery being associated with high risk of neonatal deaths (Rahman & Abidin, 2010). Conversely, a longitudinal study carried out in Tanzania did not show health delivery status having an impact on neonatal mortality (Nathan & Mwanyagala, 2012). The authors contended that their finding may be attributed to poor quality of healthcare in the study area and the lack of controlling for potential confounders such as complications during pregnancy and gestational age that have an influence on the choice of place of delivery (Nathan & Mwanyangala, 2012). There are a couple of studies that did not also show any relationship between place of delivery and neonatal mortality (Mekonnen, Tensou; Telake, Degefie, Bekele, 2013; Oti & Odimegwu, 2011; Titaley, Dibley, Agho, Roberts, Hall, 2008). Due to conflicting findings of birth place and neonatal survival, Tura et al. (2013) conducted a systematic review to pool the results of 19 primary quantitative studies in a meta-analysis to examine the effect of health facility delivery on neonatal mortality. The pooled results revealed that neonates of mothers who delivered at health facilities had a reduced mortality risk of 29%. However, there was large heterogeneity in the studies that were combined. Also, the meta-analysis by Chinkhumba et al. (2014) gave inconsistent findings as the fixed effect model was significant and the random effect model was insignificant for the inverse relationship between place of delivery and early neonatal mortality. These inconsistent findings may be attributed to high heterogeneity in studies that were pooled in the meta-analysis. In Ghana, evidence on impact of maternal healthcare delivery on neonatal mortality was limited. Welaga et al.'s (2013) study in Ghana did not show any evidence on the effect of maternal health facility delivery on neonatal mortality.

Impact of Previous Adverse Pregnancy on Neonatal Mortality

Previous adverse pregnancy outcomes (foetal deaths) such as spontaneous abortion (miscarriage), ectopic and stillbirths are noted for affecting neonatal mortality (Selemani et al, 2014; Vandresse. 2006). Previous foetal deaths are precursors to many factors that adversely affect neonatal chances of survival (Selemani et al., 2014; Tymicki, 2009; Vandresse, 2006). For instance, the presence of genetic diseases lead to foetal, neonatal and infant deaths and thus make neonates born to women who have experienced foetal deaths previously more likely to die (Vandresse, 2006). Moreso, evidence from literature shows that women who experience foetal deaths or poor pregnancy outcomes tend to become pregnant again within a very short interval and this has consequences for high risk of neonatal mortality (Selemani, et al., 2014; Tymicki, 2009). Other sources have observed that previous foetal deaths are linked to the reproductive capacity of women since these deaths might indirectly represent deficient biological mechanism of women's reproductive capacity (Tymicki, 2009; Vandresse, 2006). Studies on determinants of stillbirths have been undertaken in Ghana (Engmann et al., 2012; Edmond et al., 2008). However, studies regarding the direct impact of previous stillbirths or other foetal deaths on neonatal mortality in Ghana is not readily available in the literature.

Influence of Gravidity on Neonatal Mortality

It has been established that gravidity helps to understand the mechanism that leads to neonatal mortality better (Berhan & Berhan, 2014) yet only few studies have studied how gravidity influences risk of neonatal mortality. This may be due to lack of appropriate data to conduct research of this nature. Also, most of the studies that considered interval between successful pregnancies on neonatal mortality rarely considered the foetal deaths (miscarriages, ectopic and stillbirths) that occurs between the successful live births which may give a true reflection of birth intervals between two consecutive neonates (Bashir, Ibrahim, Bashier, Adam, 2013; Kayode et al., 2014; Mekonnen, Tensou, Telake, Degefie, Bekele, 2013; Selemani et al., 2014; Sutan & Berkat, 2014; Titaley, Dibley, Agho, Roberts, Hall, 2008). Hence, controlling for gravidity in studies that investigate determinants of neonatal mortality is necessary. A couple of studies carried out in Kenya and Tanzania to investigate the effect of gravidity on early neonatal survival did not show any effect of gravidity on neonatal mortality (Ramaiya, Kiss, Baraitser, Mbaruku, 2013; Yego, D'Este, Byles, Nyongesa; Williams, 2014). However, this study looked at the impact of gravidity on neonatal deaths in the Kintampo Districts.

Birth order of Neonates and its Influence on Neonatal Mortality

Besides maternal factors, neonatal characteristic such as birth order status is found by several studies to influence neonatal mortality (Debelew, Afework, Yalew, 2014; Kamal, 2012; Rahman, 2009; Rahman & Abidin, 2010; Singh, Kumar & Kumar, 2013). Even infant and child mortality are also affected by birth order status (Adedini et al., 2015; Buli, 2013; Ntenda, Chuang, Tirunah, Chuang, 2014). The relationship between birth order and neonatal, infant and child mortality is established to be U-shaped as it is found to be higher at the lower and upper ends (Gyimah, 2002b; Vandresse, 2006). This means that the risk of child's death is higher at the first order birth but decreases for second and third order births and then rises after that (Gyimah, 2002b; Vandresse, 2006). In Bangladesh, Rahman and Abidin's (2010) study concluded that neonates with first order birth status had almost twice the risk of death as compared with those of birth order 2-3. This was followed by Singh and colleagues' (2013) study in India that demonstrated that neonates with higher birth order have a decreased risk of dying than first order births. Besides Ntenda et al. (2014) and Adedini et al.'s (2015) studies in Malawi and Nigeria found higher birth order to have significant reduced risk of death among infants and children respectively.

In Ethiopia, a multilevel study carried out by Debelew and colleagues (2014) concluded that first and higher birth order statuses of neonates were associated with higher risk of neonatal mortality. A couple of studies however did not find a significant effect of birth order status on neonatal and child mortality (Bashir, Ibrahim, Bashier, Adam, 2013; Mekonnen, Tensou; Telake, Degefie, Bekele, 2013).

In Ghana, a study undertaken by Gyimah (2002b) found that first birth order infants have higher risk of deaths than infants with birth order status between 2 and 3. On the contrary, the findings of Kayode et al. who also studied neonatal mortality in Ghana was not in line with Gyimah's finding. Perhaps the difference might have arisen from disparity in study designs where the latter study controlled for community level factors.

The possible mechanism that explains birth order effect is the competition among siblings for parental resources and mother's attention and as a result the youngest child suffer and consequently having least chance for survival (Gyimah, 2002b; Tymicki, 2009). Another explanation offered is the youngest child's high risk being associated with maternal depletion which results from repetitive childbirths (Gyimah, 2002b; Tymicki, 2009). With regards to the high risk of death associated with first order birth, the possible explanation is that many mothers are likely to be very young by then and may not be physiologically, economically and psychologically prepared at the time of their first childbirth which therefore poses a high risk for the neonate (Gyimah, 2002b; Vandresse, 2006).

Sex of Neonates and its Impact on Neonatal Mortality

Sex of neonates is a factor which is amplified by the literature to be associated with high risk of death (Bashir, Ibrahim, Bashier, Adam, 2013; Mekonnen, Tensou; Telake, Degefie, Bekele, 2013; Buor, 2003). Evidence available shows that males are more susceptible to death in the neonatal period (Kumar, Singh, Rai, Singh, 2013; Titaley, Dibley, Agho, Roberts, Hall, 2008). The plausible explanation for such sex influence is due to immunodeficiency among male neonates which leads to increased risk of late maturity among them and also congenital malformation of the urogenital system (Singh, Kumar & Kumar, 2013; Titaley, Dibley, Agho, Roberts, Hall, 2008). This reason makes the immune system much weaker among male neonates and thereby making them vulnerable to infectious diseases and ultimately death (Tymicki, 2009; Singh, Kumar & Kumar, 2013; Titaley, Dibley, Agho, Roberts, Hall, 2008).

However, excess mortality has been previously reported among female children in certain cultures of Asia, Middle East and North Africa as a result of discrimination associated with nutrition and access to healthcare (Shell-Duncan & Obiero, 2000). On the contrary, the inherent genetic and biological makeup of boys which make them more vulnerable is the key mechanism attributed to higher risk of death among male children in sub-Saharan Africa (Shell-Duncan & Obiero, 2000).

The Ghana Demographic and Health Survey (2014) data shows that proportion of male deaths were higher among neonates, infants and children. Studies conducted in Ghana have indicated a higher risk of neonatal mortality among male neonates but this effect was not significant (Kayode et al., 2014; Welaga et al., 2013).

Impact of Gestational Age on Neonatal Mortality

Gestational age of foetuses determines the preterm status of newborns (Vandresse, 2006; WHO, 2012). The World Health Organisation defines preterm as all births before 37 completed weeks of gestation or fewer than 259 days since the first day of the woman's last menstrual period (WHO, 2012). Categorising gestational periods into <28, 28-<32 and 32-<37 completed weeks are termed as extremely preterm, very preterm and moderate preterm respectively (WHO, 2012). Although it has been far advanced in literature that lower preterm gestation is associated with higher risk of death, the cut-off period of 37 weeks is considered somewhat arbitrary (Marchant et al, 2012; WHO, 2012). This is because it has been shown that newborns with 37 or 38 completed weeks of gestation have higher risk of death in comparison with 40 completed weeks of gestation (WHO, 2012). Therefore, considering gestation periods of neonates on the risk of death will be more appropriate than just considering preterm and term statuses of neonates. Sharma (1997) was able to demonstrate in his study undertaken in the U.S.A that there was an increased risk of death as the gestational age decreases. Many studies carried out in Asia and Africa on the effect of preterm on neonatal mortality supported this finding (Debelew, Afework, Yalew, 2014; Marchant et al., 2012; Nisar & Dibley, 2014; Shah et al, 2014; Sutan & Berkat, 2014, Welaga et al). The similarity in all these studies is that they compared the various categories of preterm status with term births (37+ completed gestational age). This shows that there is a gap in examining the pattern of increasing gestational age with neonatal mortality in Africa.

Only a few studies have been conducted on the impact of gestational age on neonatal mortality in Ghana. Welaga et al.'s (2013) study in Ghana concluded that very preterm status has a higher risk of neonatal mortality compared with term births (Welaga et al., 2013). This finding was in line with another study carried out in Ghana in which term neonates had 5-fold likelihood of survival as compared to neonates who were born preterm (Annan & Asiedu, 2018).

Although preterm births are caused by variety of factors, the mechanism through which they occur have been categorised into two broad factors; spontaneous and provider- initiated preterm birth (Howson, C. P., Kinney, M. V., & Lawn, J. E., 2012). Spontaneous preterm birth refers to the onset of spontaneous labour or premature rupture of membranes prior to labour. Provider-initiated preterm birth on the other hand refers to induction of labour or elective caesarean birth before 37 completed weeks of gestation or other non-medical reasons. Spontaneous preterm birth is considered as a multifactorial process which results from interactions of factors that compels the uterus to change from its inertness to active contractions leading to birth before 37 completed weeks of gestation. (Howson, C. P., Kinney, M. V., & Lawn, J. E., 2012) Based on available literature, the cause of spontaneous preterm birth is usually unidentified in half of the cases. However maternal history of preterm birth, young or advanced age, short birth intervals, multiple pregnancy birth and low maternal body mass index are some of the factors identified to be associated with preterm birth which ultimately results in high risk of neonatal mortality (Goldenberg, Culhane, Iams, Romero, 2008; Muglia & Katz, 2010; Plunkett & Muglia, 2008).

Overview of Spatial Impact on Neonatal Mortality in sub-Saharan Africa

Variation in child mortality differs across countries, regions within countries and even within districts of regions within a country (Annan & Asiedu, 2018; Kuate-Defo & Diallo, 2002; Mekonnen, Tensou; Telake, Degefie, Bekele, 2013; Sartorius, Sartorius, Chirwa, Fonn, 2011). This makes identifying high risk geographical areas for targeted intervention for neonatal mortality very important. Studies have been undertaken in sub-Saharan Africa to analyse mortality clustering of infants and under-five children but information on neonatal mortality clustering is very limited in the region. However, reducing neonatal mortality is a crucial determinant of the decline in under-five and infant mortalities in sub-Saharan Africa.

The current available literature is on a study that investigated pattern of all-cause neonatal mortality clustering across 49 African countries including Ghana (Kayode et al, 2016). The study did not find any clustering of all-cause neonatal mortality across the countries (Kayode et al., 2016). Rolling out intervention for a whole country is very costly and it will therefore be appropriate to identify high risk areas to make cost-effective interventions. Moreso, identifying high risk areas for cause-specific neonatal mortality will further reduce intervention cost for neonatal mortality since it will also help in identifying burden of specific neonatal diseases peculiar to specific areas for prompt targeted solution. Mortality clustering studies that were conducted in Tanzania, South Africa and Burkina Faso considered villages as units of clustering (Becher et al, 2016; Lutambi, Alexander, Charles, Mahutanga, Nathan, 2010; Sartorius, Kahn, Vounatsu, Collinson, Tollman, 2010). This means that any cluster identified in the studies consisted of village or group of villages. In Tanzania, Lutambi et al. (2010) found a variation of under-five mortality risk among village clusters. Sartorius and his co-investigators (2010) also identified high risk areas for all-cause and cause-specific mortalities for neonates and infants respectively in rural South Africa. In Burkina Faso, Becher et al. (2016) found variation among village clusters in relation to under-five mortality. Other mortality clustering studies for under-five children carried out in Gambia (Quattrochi, Jasseh, Mackenzie, Castro, 2015) and Nigeria (Alabi, Baloye, Doctor, Olugbenga, Oyedokun, 2016) with unit of clustering being compounds (group of households), also corroborated these findings.

The unit of clustering being the compound is an indication that clusters identified in the studies were either a compound or group of compounds. Apart from Sartorius et al.'s (ibid) study in South Africa that investigated clustering for all-cause neonatal mortality, none of the studies investigated neither all-cause nor cause-specific neonatal mortality clustering. In addition, Sartorius et al. (2010) did not investigate clustering due to cause-specific neonatal mortality despite having investigated all-cause neonatal mortality. Meanwhile, many countries in sub-Saharan Africa including Ghana have budgetary constraints for health resources (WHO, 2015) and therefore require information about geographic hot-spots for both all-cause and cause-specific neonatal mortality. Such information will inform decision-making in the judicious allocation of limited resources (Osei & Stein,

2017) meant for the control of neonatal mortality which constitute highest proportion of huge burden of under-five deaths in sub-Saharan Africa (UNICEF, 2015). Population-based interventions are very useful means of preventing large numbers of people from morbidities and mortalities but can be a huge undertaken and expensive. Hence when population-based interventions for neonatal mortality are expensive to implement, it is necessary to identify high-risk mortality clusters and provide them (clusters) with the needed resources which are less expensive and more useful to poor resource settings in sub-Saharan Africa (Sartorius, Kahn, Vounatsu, Collinson, Tollman, 2010).

In Ghana spatial clustering of under-five mortality has been investigated in a couple of studies (Adjuik, Kanyomse, Kondayire, Wak, Hodgson, 2010; Nettey, Zandoh, Sulemana, Adda, Owusu-Agyei, 2010). Nettey et al. (2010) and Adjuik et a.l (2010) used villages as units for clustering and were able to identify high-risk areas for under-five mortality clustering. Clustering for neonatal mortality which constitutes 48% of under-five mortality in Ghana (GSS, GHS & ICFI, 2015) was disregarded in these studies. However, MDG 4 of reducing under-five mortality by two-thirds was not achieved by Ghana and Ghana is currently striving to achieve SDG 3.2 which has targets of reducing neonatal and under-five mortality rates to 12 and 25 deaths per 1000 live births respectively. Hence, knowledge of all-cause and cause-specific neonatal mortality clustering will make intervention for neonatal mortality more focused and less expensive (Osei & Stein, 2017); and subsequently contribute to the achievement of SDG 3.2 in Ghana.

CHAPTER THREE

THEORETICAL AND CONCEPTUAL FRAMEWORK

Introduction

This chapter presents the theories and conceptual framework that guided this work. It also critiques various conceptual frameworks on child mortality and the application of these frameworks in past studies. Finally, there is a justification for adapting a conceptual framework that is suitable for this work.

Theoretical Works Underpinning the Study

The study has its underpinning in three theories which support the idea that community where children are born or raised has impact on its health outcomes (Ellen, Mijanovich & Dillman, 2001; Galster, 2010; Vandresse, 2006). Ellen et al.'s (2001) theoretical work of "neighbourhood effects and health" support the idea that the neighbourhood (or community) could influence health outcomes of the child through four pathways which are (a) neighbourhood institutions and resources; (b) stresses in physical environment; (c) stresses in social environment; and (d) neighbourhood-based networks and norms. Regarding (a) this framework established that institutions such as healthcare facilities could influence individual health outcomes. For instance, presence of healthcare facility in the neighbourhood increases the chances of child survival. Moreover, under (b) the authors argued that resources such as the opportunity for community members to interact and have access to good nutrition have implication for improvement in individual's health. Within the context of child survival, mothers with access to good nutrition and opportunity to interact with members of the community who are knowledgeable in healthcare issues, have a higher tendency to improve their health and the survival of their children; as supported by empirical works of Kravdal (2004) and Andrzejewski et al. (2009). Ellen et al. (2001) advanced the argument in (c) by linking quality of the neighbourhood environment to individual health outcomes. For example, poor sanitation within the community has adverse effect on child survival as established by Fuller et al. (2016) and Harris et al.'s studies (2017). Furthermore, the framework contended in (d) that social condition in the neighbourhood may pose threat to the health of individuals within the community. For example, stress from the environment may aggravate hypertension and other stress related disorders of the pregnant woman which can influence her to engage in unhealthy behaviours such as drinking and smoking.

These unhealthy behaviours could affect the foetus and consequently the health of the newborn. Vandress' (2006) feto-infant theory was able to establish that the residential environment might have effect on biological variables of the foetus, infant or the mother and those variables might in turn influence foetus or infant mortality. Therefore, the biological variables are called proximate variables. Vandresse classified the variables which determine feto-infant mortality into five main domains as socio-economic characteristics, environmental characteristics, parental age, behavioural characteristics and biological characteristics.

The socio-economic characteristics are those characteristics of the parents such as income, educational level, marital status and occupation that can influence the mortality of the infant or foetus. Environmental characteristics links the quality of environment in the region where one resides to feto-infant mortality. Such characteristics include housing quality; climate; air, water, ground or food pollution etc. Parental age has to do with the age of the parents at the time the woman conceived or delivered. The age at which the mother delivers for instance, has been established by empirical studies to influence child survival (Huda, Tahsina, Arifeen, Dibley, 2016; Kamal, 2012; Mekonnen, Tensou; Telake, Degefie, Bekele, 2013; Singh, Kumar & Kumar, 2013). She classified behavioural characteristics as healthcare behaviour of the mother that may influence infant or foetal mortality and that includes pre- and post-natal care; drinking and smoking habits; nutrition etc. Finally, biological variables were considered as variables that have direct impacts on infant or foetal deaths. Vandresse opined that biological variables encompass maternal characteristics (reproductive history, general health state during pregnancy and breastfeeding), foetal characteristics (child characteristics at birth which includes gestation, birthweight etc.) and obstetric characteristics (complications during delivery).

Galster's neighbourhood effect theory (2010) supported the idea that health outcomes of the child is linked to his/her residential environment. Galster (2010) theorized fifteen potential causal pathways between neighbourhood characteristics and individual's behavioural and health outcomes. The potential causal pathways were organised into four broad areas namely social interactive, environmental characteristics, geographical characteristics and institutional characteristics which encompass all the domains of the afore-mentioned theoretical works.

Conceptual Frameworks

Various conceptual frameworks underlie child health outcomes. This section critiqued four major conceptual frameworks and the one that best fits the available data for this study was chosen. The following conceptual frameworks were examined: (a) WHO's Commission on Social Determinants of Health (CSDH) framework; (b) UNICEF's Structural Determinants of Child Well-being framework; (c) Mosley and Chen framework; and (d) Sastry framework of child mortality clustering

CSDH Framework

This conceptual framework draws upon the work of World Health Organisation's Commission on Social Determinants of Health which was established in 2005. As depicted in Figure 1, the framework hypothesises that socio-economic and political context (such as government policies, cultural and societal norms) in the upstream macro-level stratify the population into social positions according to income level, educational level, type of occupation, gender inequities and racial (or ethnic) inequities. These social positions in turn shape specific determinants of health status (intermediary factors) such as material circumstances, social cohesion, psychosocial factors, behaviours and biological factors which are a reflection of individuals' place within social hierarchies (or strata). The resultant effect of this pathway leads to differential exposures and vulnerabilities of individuals which consequently leads to inequities in health outcomes. The undesirous health outcomes of individuals may have a reverse impact on their social positions or socio-economic and political context. For instance, individuals' ill health can reduce their income or employment opportunities. In addition, outbreak of certain diseases such as cholera and ebola can have effect on the socio-economic and political landscape. (Solar & Irwin, 2010; WHO, 2011)

Generally, this framework can be adapted in neonatal, infant or child mortality studies (Kim & Saada, 2013) but the context within which the health of individuals are affected extends up to macro-level determinants which will be a limitation for the available dataset considered in this study.

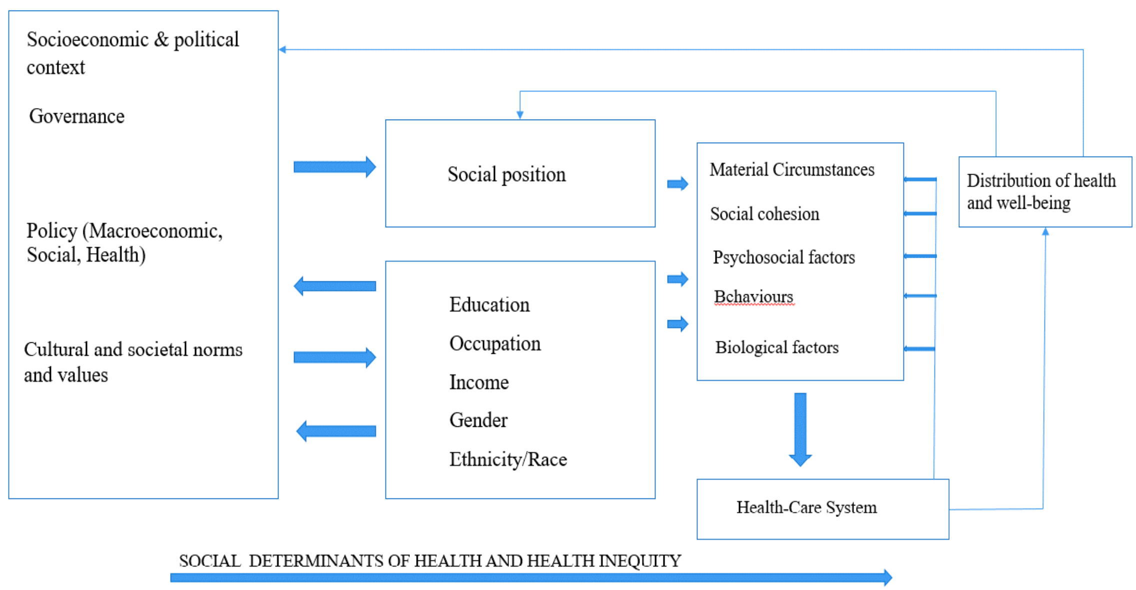


Figure 1: Commission of Social Determinants of Health Conceptual framework linking social determinants of health and distribution of health

Source: World Health Organisation (2011)

Application of CSDH in Empirical Literature

This framework has been applied to a number of studies in the developing countries. Mmusi-Phetoe study in South Africa was guided by CSDH framework. She investigated the effect of socio-economic status on neonatal and maternal mortality. The researcher found that poverty played a key role in determining neonatal and maternal mortality. Intermediate factors that had influence on maternal and neonatal mortality were inadequate nutrition, health system issues, HIV or AIDs, neglect and abuse by male partners and reproductive health issues.

Mugo et al.'s (2018) study in South Sudan was conceptualised based on the CSDH framework. The aim of the study was to find factors that were associated with neonatal, infant and under-five mortality. Mothers who reported a previous death of a child and to be dwelling in an urban area were found to be associated with a higher risk of neonatal, infant and under-five mortality. However, improper source of drinking water was the only factor that was significantly associated with a higher risk of neonatal death. The author therefore argued that the condition and circumstances in which a child is born into or raised, play a role in under-five mortality.

Kim and Saada's (2013) systemic review of empirical studies on the social determinants of infant mortality/birth outcomes was guided by CSDH framework. The review sought to understand unequal distribution of within and cross-country infant mortality and/or birth outcomes such as foetal deaths, neonatal mortality etc. Within-country and cross-country variation in the outcome (infant mortality/birth outcome) were considered for United States of America (USA) and countries in Western Europe. The review found income inequality and social policies as possible underlying causes for the variation of infant/birth outcomes across countries. Social determinants that were found to be the possible explanation for the variation in infant mortality/birth outcomes within countries were income inequality and socio-economic status of neighbourhoods.

This framework has a strength of its applicability in both advanced and developing countries. It is also suitable for data which consist of both micro and macro variables. Additionally, it has a strength of applying equity to elicit differential health outcomes. However, it has a limitation of its applicability to only micro-level data.

Structural Determinants of Child Well-Being Framework

The structural determinants of well-being involves a shift from interventions that are directed towards change at the individual child or family (or household) level. However, it rather looks at more comprehensive programmes that focus on social and structural components (government policies, health systems in countries etc) that are seen as critical and therefore becomes an explicit target for policy action and advocacy; with the aim of providing the enabling environment. The aim of structural approaches is to modify social conditions and arrangements by means of addressing the key drivers of children's vulnerability. They also include actions that focus on factors that serve as barriers to individual child or family so that they can benefit from existing services. An example is to modify services where vulnerable groups in a country do not have the ability and are willing to use them. (UNICEF, 2012)

Figure 2 depicts the framework that have identified four major domains to codify structural determinants in the areas of political, historical and economic;

demographic, geographic and environment; governance and human rights; and social, cultural and norms. The critical macro actions that were considered by the framework to span public and private modalities are systems (health systems, educational systems, public administration, child protection and social protection), institutions (religious, media, markets and human rights) and policy processes (legislation, taxation, public policy and gender equality). The framework puts forward that micro-actions of actors occur through communities, families (or households) and at the individual to exert impact on child well-being at the material, relational and subjective levels. Hence, the framework advocates for integration of these inter-sectoral and comprehensive approaches; recognising the interplay of structural factors that build synergy to ultimately have impact on child well-being. The framework has the following key principles: child centred; incorporates global and macro-processes; appreciates multi-directionality; multi-dimensionality and multi-sectorality; does not lose sight of complexity but easy to conceptualise; measurable and linked to well-being outcomes; contextual to varying (micro) environments; actionable and amenable programming; and consistent with post 2015 MDG framework and builds on existing work. (UNICEF, 2012)

It has been recommended that this framework needs to be operationalised at the country level and in fact the main target as a user for this framework are national level policy makers and partners. However, it can also be applied by local authorities or communities to assess their own situation and subsequently support their initiatives irrespective of support from higher authority. (UNICEF, 2012) The factors that the framework touched on were not consistent with the available dataset for this study. In addition, the factors considered in the framework includes macro-level factors which are not consistent with the dataset of this study.

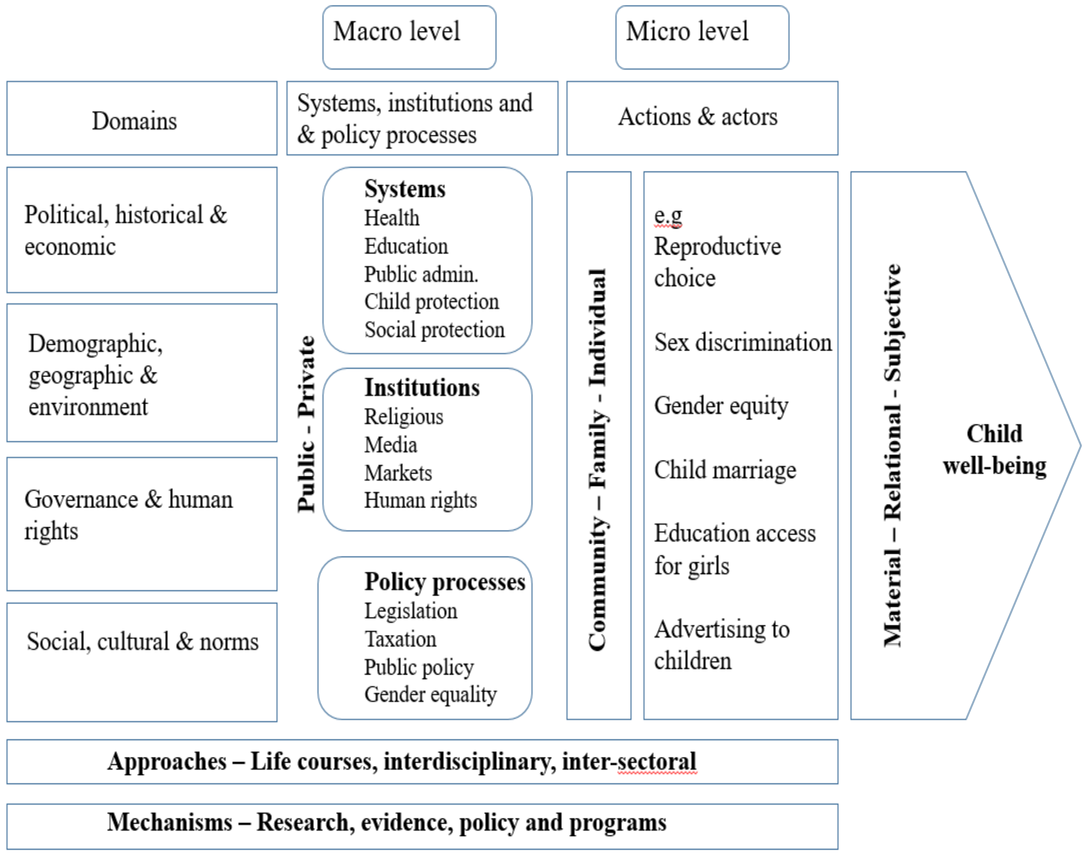


Figure 2: A Proposed Framework for Analysis of Determinants of Child Well-being

Source: UNICEF (2012)

Application of Structural Determinants of Child Well-Being Framework in Empirical Literature

The application of this framework in empirical studies was not readily available. This framework has a strength of its application in the macro level by using the multi-sectorial approach. Its applicability in developing countries with religious and cultural diversity is limited. It also has a limitation of not suitable for micro level datasets.

Mosley and Chen Conceptual Framework

This framework proposed by Mosley and Chen in 1984 was for the analysis of child survival in developing countries. This framework is based on the premise that all socio-economic determinants operate through a common set of biological mechanisms, called proximate determinants, to exert impact on child mortality. There are five sets of proximate determinants which are (a) maternal factors; (b) environmental contamination/factors; (c) nutrient deficiency; (d) injury and (e) personal illness control factor. This proximate determinant framework links the individual child's death with the underlying socio-economic determinants (or factors) which are considered to be in three broad categories (or levels) namely individual, household and community levels.

This framework which is an integration of both social and biological factors have a total of fourteen sub-categories under the five broad categories of proximate determinants. The maternal factors consist of age, parity and birth space. Since these maternal factors affect maternal health, they have independent outcomes on pregnancy outcomes and child survival. The next factor which is environmental contamination consists of four factors which are air; food, water and fingers; skin, soil and inanimate objects; and insect vectors. Environmental contamination refers to the transmission of infectious agents to the child, mother or both. The four major factors of environmental contamination serves as the main routes for the transmission of infectious agents. Nutrient deficiency, on the other hand, is related to the intake of three major classes of nutrients namely calories, protein and micronutrients. The availability of nutrients to mothers during pregnancy is vital for foetal development whereas nutrient available to mothers during the postpartum period influences survival of the child. The fourth factor which is injury has two major sub-categories of accidental and intentional injuries and these include physical injury, burns and poisoning. Personal illness control factors consist of preventive measures and medical treatment. It refers to practices and quality of care during pregnancy and childbirth which are related to the child survival.

The factors of the first four major determinants influence the rate at which children move from a healthy condition to sickness. The personal illness control factors influence both the rate at which children shift from healthy condition to sickness (through prevention) and the rate of recovery (through treatment). The consequences of the child sickness may lead to growth faltering (which may subsequently result in death) or death as depicted in Figure 3 (Mosley & Chen, 1984).

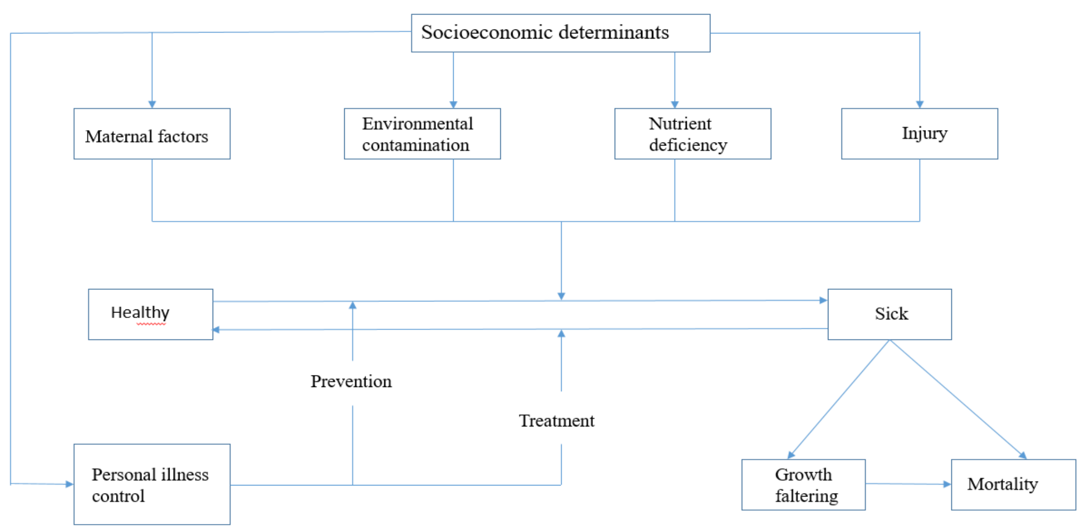


Figure 3: Operation of the five groups of proximate determinants on the health dynamics of a population

Source: Mosley (1984)

The Mosley and Chen framework was consistent with the data for this study to some extent since it has three levels. However, while this work considered only individual, household and the community and their effect on neonatal mortality, the Mosley and Chen framework considered the three factors as socio-economic determinants and linked them to child death through a set of common proximate determinants.

Application of Mosley and Chen Framework in Empirical Literature

Mosley and Chen framework has been applied in several studies in developing countries. Meckonnen et al. study (2013) adapted the framework to determine contextual, socio-economic, proximate factors and maternal health service use affecting neonatal mortality in Ethiopia. The study revealed that contextual, socio-economic, proximate and maternal service use were associated with risk of neonatal mortality. This was followed by a study undertaken in Ghana by Kayode et al. (2014). The framework guided Kayode et al.'s study to determine the effect of individual- and community-level characteristics on neonatal mortality. Guided by Mosley and Chen framework, Khadka and team of investigators (2015) found community level socio-economic and proximate factors as determinants of infant mortality in Nepal. Additionally, Maniruzzaman et al.'s (2018) study in Bangladesh which modelled neonatal and child mortality employed this framework. In 2019, Liwin and Houle work were guided by this framework, which aided them to demonstrate that child, maternal and community characteristics were associated with high risk of child mortality in Sierra Leone. Mosley and Chen framework has an advantage of its wide applicability in many developing countries with different cultures, healthcare infrastructure and system, and cultures. The limitation of this framework is its suitability for only developing countries.

Sastry Conceptual Framework

This conceptual framework hypothesises that children in the same family and community are exposed to common risk of death which are measurable (observed risk) and unmeasurable (unobserved risk). Sastry (1997b) categorised these common risk factors into three broad categories namely genetic, behavioural and environmental factors. He argued that these risk factors occurs at the individual, family and community levels. Sastry (1997b) further emphasised that individual level factors are nested in family level factors which are in turn nested in community level factors and thus form a logical hierarchy. Due to the logical organisation of these factors in the framework, Sastry (1997b) posited that it is analogous to Mosley and Chen framework and therefore his model forms the basis of Mosley and Chen conceptual framework of child mortality.

Figure 4 depicts the Sastry framework for child mortality in which at the individual level child mortality is mainly attributed to idiosyncratic (peculiar to a specific individual) genetic factors and child-specific behaviour and care which fall under the two broad categories of genetic and behavioural factors respectively. Here, Sastry argued that though there are some causes of child deaths that are due to exogenous factors such as infanticide, the majority of the causes are due to genetic factors. He therefore argued that even infectious diseases which are attributable primarily to factors such as poor living conditions and environmental contamination have genetic components because genetic variation is the underlying factor that differentiates the susceptibility of children to these diseases. Moreover, the behavioural factors at the child level may be due to level of care given to the child by the mother. This level of care associated with factors such as duration of breastfeeding and accessibility and timely vaccination may pose a risk of death as espoused by Sastry (1997b). This same reason extends to the family level where children of the same mother are likely to be exposed to common risk factors because of the level of care exhibited by their mother.

In addition, the father's behaviour towards healthcare such as the negligence of providing the necessary resources required for good healthcare for his children may also pose risk of death at the family level. Common genetic factors shared by children of the same family also expose them to risk of death and as a result of that, risk of death is likely to differ from one family to the other. Besides, children of the same family have a common household environmental factors such as quality of drinking water, household socio-economic status and crowding which may expose them to common risk of death. At the community level, genetic factors are not likely to expose children to common risk of death but rather behaviourial characteristics such as cultural values, norms and preferences. With regards to environmental factors at the community level, Sastry posited that children share the same climatic conditions, infrastructure and physical environment and that expose them to common risk of death in the community. (Sastry, 1997b)

This conceptual framework is consistent with the available data for this work. Hence, this framework was adapted for this work.

		Form of effect		
		Genetic	Behavioural	Environmental
	Child	Idiosyncratic genetic factors	Child-specific behaviour and care	
Level of operation	Family	Genetic factors shared among all siblings	Parental competence, care of children common to all siblings	Household environment
	Community		Shared preferences, values and cultural influences	Infrastructure, climate, physical and disease environment

Figure 4: A framework depicting factors influencing risk of child mortality at the individual child, family and community level

Source: Sastry (1997b)

Application of Sastry Framework to the Study

The Sastry model provides the analytical framework for this study with clustering of child mortality generally at the individual, family and community levels. However, the family level was considered as household level in this study. In order for the variables of this study to fit into the tenets of this framework, they were specified at the three main levels of operations namely individual, household and community levels. The framework was therefore applied to this work to answer the study hypotheses to fill the identified research gap.

Situating this study in the adapted conceptual framework, the main outcome of the study will be neonatal mortality and the individual-level variables will be the neonatal characteristics which are sex, gestational age and birth order status of neonates. Furthermore, individual maternal characteristics will also be gravidity, maternal age, tetanus toxoid vaccination status, level of education, place of delivery and previous adverse pregnancies (previous foetal deaths). Moreso, household-level variables considered were socio-economic status and crowding. In addition, the community-level variables were poverty, educational level of females (secondary or higher), quality of water, sanitation, time taken to reach water source, ethnic heterogeneity and distance to the nearest health facility. Figure 5 summarizes the adapted framework for this study.

Level of operation	**Independent variables**
Individual	<u>**Neonatal factors**</u> Sex Gestational age Birth order <u>**Maternal factors**</u> Age Previous adverse pregnancies Gravidity Educational level Place of birth Tetanus toxoid vaccination
Household	Household socio-economic status Household crowding
Community	Educational level of females Poverty Ethnic heterogeneity Sanitation Water quality Time taken to reach water source Nearest distance to the health facility

Figure 5: Adapted framework depicting potential individual, household and community level factors influencing neonatal mortality in the Kintampo sub-districts

Source: Adjei (2019)

Application of Sastry Framework in Empirical Literature

Sastry's framework has been applied in a couple of studies. In Malawi, Manda's study (2001) compared frailty models used in the analysis of child survival data and made reference to Sastry's framework. According to Manda, child survival times are clustered within the family and community. The study revealed very little variation at community level regarding child survival and considerable variation at the household level. Griffiths et al. (2004) adapted this framework to investigate the determinants of child nutrition status (weight-for-age) in six sub-Saharan African countries (Ghana, Nigeria, Malawi, Tanzania, Zambia and Zimbabwe) and four Indian states (Uttar Pradesh, Maharashtra, Karnataka and Tamil Nadu). Individual- and household-level factors such as the child's age, child's size at birth, episodes of diarrheoa, mother's educational level and duration of breastfeeding were found to be predictors of child nutritional status. This framework has a strength of its successful applicability in child mortality studies undertaken in developing countries with diverse culture and religion like Ghana, Nigeria and India. It has a limitation of its applicability to macro level data. Additionally, it has a limitation in its application to only kindred datasets.

CHAPTER FOUR

METHODOLOGY

Introduction

This chapter focused on sources of the secondary data which involves the description of the study area, (Kintampo Health and Demographic Surveillance System (KHDSS)), research design, population, sample size calculation, sampling procedure, study instruments, data collection procedure and measurement of study variables.

Sources of data

Study Area

This study used longitudinal data from Kintampo Health and Demographic Surveillance System (KHDSS) which covers almost the whole (95%) of Kintampo North Municipality (located between latitudes 8º45'N and 7º45'N and Longitudes 1º20'W and 2°1'E) and Kintampo South District (located between 1º 20' West and 2º10' East and latitude 8º 15' North and 7º 45' South) (Nettey, Zandoh, Sulemana, Adda, Owusu-Agyei, 2010; Owusu-Agyei et al., 2012). Both the municipality and district together have a total surface area of 7,162 km^2 and are located in the middle belt of Ghana. The KHDSS area is sub-divided into 12 sub-districts namely Busuama, Dawadawa, Gulumpe, Kadelso, Kintampo, Kunsu and New Longoro which are located in Kintampo North Municipality while the rest namely Amoma, Anyima, Apesika, Jema and Mansie sub-districts are located in the Kintampo South District (Nettey, Zandoh, Sulemana, Adda, Owusu-Agyei, 2010). The sub-districts constitute part of the smallest health administrative units of Ghana (Kikuchi et al, 2015). Also, the KHDSS area is located in the Brong Ahafo Region of Ghana.

Hence, Figure 6 below shows the map of Ghana, Brong Ahafo Region and the KHDSS area.

The total population and households in the KHDSS area in 2014 were 145,000 and 32,000 respectively. The main indigenous ethnic groups in the area are the Bonos and the Mos. There is however a large immigrant population from the three Northern Regions (Dagaaba, Dagomba and Konkomba) who are generally farmers. Some immigrants of Dangbe and Ewe origin, who are mainly fisher folks, are settled along the banks of the Black Volta. The settlements are mostly concentrated in the southern part and along the main trunk road linking the two district capitals (Kintampo and Jema) to Northern Region. Community members engage in farming of predominantly maize, yam and cassava. Livestock rearing of cattle, sheep, goats and birds are also common.

Each district in the KHDSS area has a hospital and other health facilities such as health centres, Community-based Health Planning and Services (CHPS) compounds and maternity homes that perform family planning services as well as maternal, child and neonatal services. CHPS compounds also embarks on outreach health services within the communities (Adjei et al., 2015).

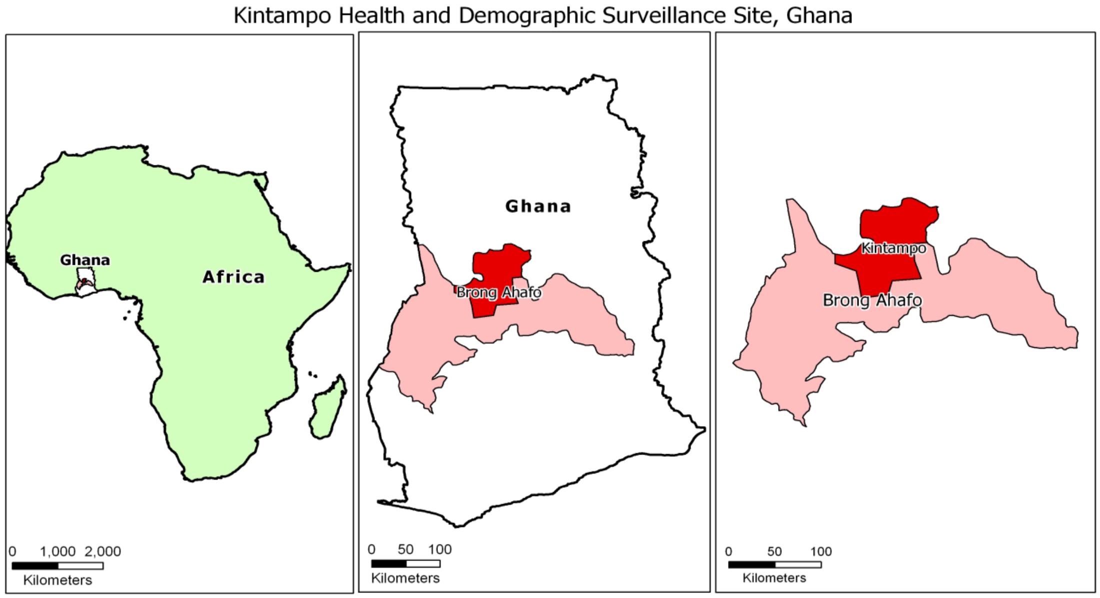


Figure 6: Maps showing the location of Ghana, Brong Ahafo Region and Kintampo HDSS

Source: Owusu-Agyei (2012)

The Kintampo Health and Demographic Surveillance System

The Kintampo Health and Demographic Surveillance System (KHDSS) collects vital demographic, socio-economic and health data at the household level. The demographic and health data were updated every 6 months (since 2003) while the socio-economic data were updated biennially (since 2005). However, the health and demographic data were updated every 4 months from January 2011 to December 2013 to ensure comprehensive recording of births, deaths and migration. Due to the lack of funds, the KHDSS reverted to six monthly update in 2014. The 6-month cycle means data from each household are updated twice each year from January to June and then from July to December; whereas the 4-month cycle means data from each household are updated thrice each year from January to April, May to August and September to December. The educational level of individuals is updated every year since it is not expected to change that much within a year.

The baseline census of the KHDSS started in November 2003 and ended in March 2004. The basic demographic routine data collected are births, deaths and migration. These demographic data are collected by well-trained fieldworkers with a minimum of secondary education. In addition to basic demographic data, pregnancy events are also recorded. Moreover, selected community members are trained by KHRC to complement the task of fieldworkers. These trained selected community members are called Community Key Informants (CKI) and their duty is to record pregnancies, births and deaths that occur in their communities in-between scheduled visits (Owusu-Agyei et al., 2012). The reason behind this, is to capture these demographic events on time and also avoid especially missing of neonatal deaths (Owusu-Agyei et al., 2012). Every pregnancy identified is monitored till the outcome of the pregnancy is captured as live birth, stillbirth, miscarriage or induced abortion. In addition to these, the gestational age is captured by determining the duration of the pregnancy through probing during the registration of pregnancies. Moreover, for every death identified, further detailed information is collected to establish the cause of death, through verbal autopsies. The socio-economic variables recorded are household assets (e.g radio, bicycle, television etc), quality of housing, sanitation etc.

All the demographic and health information are collected on the total population in the KHDSS area prospectively and therefore serves as the corner stone for all research activities in the Kintampo Health Research Centre. Besides, the centroids of all the villages and towns have been mapped using Global Positioning System (GPS). In addition, compounds (buildings/houses in which members of households reside) in all the villages have been mapped, thereby making it possible to visually link household members to their compounds in the villages and also display several output graphically. Figure 7 depicts the operation of the KHDSS

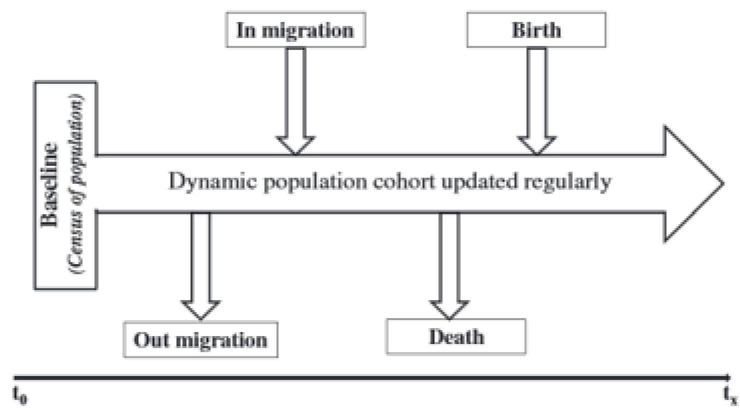


Figure 7: The structure of a Health and Demographic Surveillance System
Source: Owusu-Agyei (2012)

Research Paradigm

Paradigm is a basic set of beliefs or worldview that guides research action or an investigation (Guba & Lincoln, 1994). The worldview of the researcher is his/her perspective, thinking, school of thought or set of shared beliefs that informs the meaning and interpretation of the research data (Kivunja & Kuyini, 2017). Bhatacherjee (2012), argued that paradigm is like a reseacher's "coloured glass" that governs how he/she views the world and how he/she structures his/her thought based on what he/she sees through the glass. There are several paradigms that govern research but this study is governed by the positivist paradigm.

Positivist paradigm habours the view that science or knowledge creation should be restricted to what can be observed and measured (Bhatacherjee, 2012). Positivism holds the view that phenomena in the world can best be explained by the methods, techniques and procedures used in the natural sciences (Chilisa & Kawulich, 2011). Indeed, authors have argued that quantification using the positivist paradigm is key for objective and rigorous investigation (Broom & Willis, 2007). The central approach of positivism is deductive in nature and allows the researcher to test an existing theory or hypothesis (Broom & Willis, 2007; Kivunja & Kuyini, 2017). This idea of positivism supports this work which collected data consisting of a set of variables measured in a standard way for all the study participants and consequently testing hypotheses. Despite the strength of the positivist paradigm, it also has a limitation of its blind faith in empirical or observed data and also lacks the attempt to extend beyond observable facts (Bhatacherjee, 2012).

Research Design and Rationale

This was a longitudinal study that followed mothers and their newborn singletons in the KHDSS area over a 10-year period (January 2005 to December 2014) to ascertain risk factors of newborns' (or neonates') death. Hence, this study investigated the individual, household, community as well as spatial factors that had impact on neonatal mortality in 12 sub-districts (or communities) in the KHDSS area. The study considered the sub-districts as communities and compared their individual, household, community and spatial factors that influence only neonates who were singletons over the 10-year period.

The design for this research study was chosen because adopting a strategy or policy intervention for public health issue such as neonatal mortality requires extended period of observation for factors that predispose neonates to death (Nettey, Zandoh, Sulemana, Adda, Owusu-Agyei, 2010). It is therefore appropriate to choose a longitudinal design where study participants can be systematically monitored to ensure that risk factors preceded the outcome. Moreover, this study has a strength of monitoring individuals, households and communities concurrently and over a long period which is a limitation of other observational studies such as case control, ecology and cross-sectional studies. Since the nature of the study did not require the provision of intervention to see its effect on neonatal mortality, it will not be prudent to undertake an experimental study such as randomised controlled trial.

In addition, it has added advantage of isolating observed and unobserved risk factors. Moreover, it has the strength of reducing recall bias since risk factors are assessed before the outcome. Although this study design is suitable for this investigation, it also has some limitations. It takes much time to conduct and also requires huge resources making it expensive. In addition, this kind of study has a risk of panel attrition; this means that it is possible that, a specific group of individuals the study has decided to focus on consistently for a long period may migrate out of the study area or even die. However, all these limitations were minimal in this study since it focused on neonates who usually do not require long follow-up period.

Population

The study population was singleton neonates (0-27 days) who were alive or dead between January 2005 to December 2014 in the 12 KHDSS communities (or sub-districts).

Sample Size

The number of singleton neonates (dead or alive) selected from the KHDSS database between January 2005 and December 2014 was 30,132. Of the 30,132 neonates, 634 were deaths. Therefore, with a sample size of 30,132, neonatal deaths of 634, hazard ratio of 2.0 and a significance level of 0.05, the estimated power of this study was found to be more than 95%.

Sampling Procedure

All mothers who delivered in the study area (both at home and hospital) between January 2005 and December 2014 were accessed from the KHDSS database and linked to their newborns. This means that two or more newborns may have the same mother within the 10-year period. All multiple gestation childbirths (twins, triplets etc.) were identified and removed from the dataset. This was done because they have a high risk of deaths (Kim & Saada, 2013) and might therefore not give a true reflection of the strength of relationships between risk factors and neonatal mortality. The resultant dataset was linked to corresponding pregnancy and household datasets to have another combined dataset. The community variables were constructed from the dataset using characteristics of the total population in a given community within a particular year. For example, the proportion of women with at least high school education for a particular community in 2006 will be the ratio of the total number of women in that community in 2006 who at least completed high school divided by the total number of women in that community in 2006. Having obtained dataset for community level variables, it was linked to the latter combined dataset and the resultant dataset was merged with deaths dataset and the verbal autopsy (VA) dataset containing the causes of neonatal deaths.

Study Instruments

Four types of questionnaires were used to collect data; and these were pregnancy, births, household and VA questionnaires. The pregnancy questionnaires were used to elicit information on estimated date of conception, antenatal care information and antimalarial use in pregnancy. Also, the birth form is made up of mother's birth history and information about the neonate. The household instrument consists of ownership of household assets and services, housing quality, household sanitation, sources of drinking water, and characteristics of household head. The VA instrument had battery of questions together with narration which were used to determine the possible causes of neonatal deaths.

Data Collection Procedure

Once a pregnancy was identified, the fieldworker registered the pregnancy. The fieldworker then followed up on the pregnancy through the administration of pregnancy questionnaire to the pregnant woman on each visit till she delivered (Owusu-Agyei et al., 2012; Welaga et al., 2013). Additionally, birth forms were administered to the women when they deliver. Besides, the household questionnaire was delivered to the key informant of the household who was abreast with information about the household. The key informant could be the household head or any other member of the household who is knowledgeable about the household.

The knowledgeable member was determined by asking the member whether he/she had enough information about the household and its members. All questionnaires were administered in a language in which respondents understood and were comfortable with. The challenge of collecting this secondary data were; (a) some of the roads were bad and because of that fieldworkers found it difficult reaching a respondent's home; (b) some of respondents left home early for their farms and fieldworkers had to be in their homes very early in the morning in order to avoid missing the respondents. Field supervisors ensured that all the data collected were devoid of blanks and inconsistencies. In addition, 5% of the completed questionnaires were randomly selected by field supervisors and the interviews re-done to ensure data quality.

Variables and their Measurement

This section deals with variables that were considered in the study and how they were measured.

Dependent Variable

Since time to the death was modelled in this study, dependent variable (or outcome) of this study was the probability (or risk) of neonatal death. Once there was a childbirth, the baby's date of birth was captured in a birth form (or questionnaire). Whenever there was an event of death the date of death was also captured on a death form. All these records were entered in the KHDSS database. Hence all deaths (excluding multiple gestation) that occurred within the first 28 days (day 0 to day 27) were retrieved from the KHDSS database and identified as neonatal deaths.

Independent Variables

The independent variables in this study were classified as individual, household and community level variables.

Individual Level Variables

Individual level variables were neonatal and maternal characteristics. The neonatal characteristics include sex of the neonate, birth order and gestational age. The sex of the neonate was captured on the birth form. The birth order was captured from the birth history on the birth form which gave information on the number of previous live births of the mother. Additionally, the gestation age of the neonate was estimated based on the estimated date of the mother's conception. This was captured on the pregnant form and this was done as soon as the pregnancy event was identified and registered in order to reduce recall bias. Since the date of birth was captured on the birth form, the gestational age was calculated in weeks by considering the difference between the estimated date of conception and the date of birth.The maternal characteristics include maternal education, place of delivery, maternal age at birth, tetanus toxoid vaccine status, gravidity and previous adverse pregnancy (stillbirth, abortion and ectopic). Maternal education was captured from an education form which was administered to household members in KHDSS area annually. This form was administered annually because the educational status of an individual was not expected to change that much within a year. The place where the pregnant woman delivered was captured on the birth form to determine whether the woman delivered in a health facility or outside the health facility. Maternal age at birth was estimated from the maternal date of birth captured on the individual form and the date of childbirth captured on the birth form. In addition, tetanus toxoid vaccine status of the mother was determined from the pregnancy form. The pregnancy form collected information on tetanus toxoid status of the mother during her pregnancy period. This was done by confirming from her antenatal care card as to whether she had received the vaccine. Hence, tetanus toxoid vaccination status of mothers throughout their pregnancies was identified from the KHDSS database. Moreso, the number of pregnancies the women had ever had (gravidity) was captured on the birth form. Women were asked the number of pregnancies they had ever had including the current one. To ensure validity of mothers' gravidity, they were further asked questions based on birth history such as number of miscarriages (abortion), number of children who had died, number of stillbirths etc. If there were discrepancies in the total number of pregnancies and the number deduced from the birth history, mothers were probed further to rectify this anomaly. The previous adverse pregnancies also known as foetal deaths were elicited from birth history on the birth form. Mothers were asked whether they had ever had abortion (miscarriages), ectopic or stillbirths. Table 1 depicts how the individual level variables in the study were coded.

Table 1 : Coding of Individual Level Variables

Number	Variable	Description	Code
1	Sex	Sex of the neonate	[1] Male; [2] Female
2	Birth order	The rank of the neonate according to the order of birth	[1] 1; [2] 2-3; [3] 4+
3	Gestational age	Gestational age of the neonate	Gestational age in weeks
4	Maternal age	Age of the mother at birth	[1] Less than 20 years; [2] 20-34 years; [3] Above 34 years
5	Level of education	Maternal level of education in the year of birth	[1] No formal education; [2] Primary; [3] Middle/JSS/JHS; [4] Secondary/SSS/SHS or above
6	Tetanus toxoid vaccination	Tetanus toxoid vaccination status of the mother during pregnancy	[1] Yes; [2] No
7	Gravidity	Total number of pregnancies the mother ever had	[1] 1; [2] 2-4; [3] 5+
8	Previous adverse pregnancies	Previous pregnancies that resulted in miscarriage, ectopic or stillbirth	[1] Yes; [2] No
9	Place of delivery	Place where the neonate was delivered by the mother	[1] Hospital; [2] Health Centre/Clinic; [3] Private Maternity Home; [4] TBA's House; [5] At Home; [6] Other

Source: Adjei (2019)

Household Level Variables

The household level variables consist of household wealth and crowding. Household variables were captured every two years using the household form. The household wealth status which includes household assets and services as well as housing quality was determined by using a statistical technique called Principal

Component Analysis (PCA) to construct a wealth quintile index. This index served as a proxy for household socio-economic status in this study. The household assets data includes over 20 variables made up of household assets and services such as building, car, motorcycle, television, radio, bicycle, farm, table, sleeping mattress, gas cooker, livestock, electricity etc. Housing quality includes materials used for roofing, floor and wall of the building. Since asset data were captured every two years, the household wealth status for a previous year was the same for the following year. For example, wealth index for 2005 was the same as 2006. The wealth index has been shown to be robust and stable and for that reason does not change significantly (Schellenberg et al., 2005). Therefore, the wealth index was not expected to change significantly within a year.

Principal Component Analysis

The PCA creates uncorrelated components from an initial set of correlated variables, where each component is a linear weighted combination of the initial variables (Vyas & Kumaranayake, 2006). The first component which explains the largest possible amount of variation in the original dataset was divided into household wealth quintiles (Filmer & Pritchett, 2001; Vyas & Kumaranayake, 2006). The quintiles which were labelled poorest, poorer, third, fourth, wealthiest served as a proxy for household socio-economic status. For example, for n number of correlated variables from X_1 to X_n, the uncorrelated PCA components are given by

$$PC_1 = a_{11}X_{11}+a_{12}X_2 +\ldots+ a_{1n}X_n$$

. .

.   .

.   .

$PC_m = a_{m1}X_{m1} + a_{m2}X_2 + \ldots + a_{mn}X_n$

Where a_{mn} represents the weight for the m^{th} principal component and n^{th} variable.

Household Crowding

Household crowding was estimated by dividing number of people in the household by the number of sleeping rooms in the household. Household crowding was also the same for the previous and following year since the data used to estimate household crowding were collected biennially. This was not expected to change significantly within a year since the wealth status of a household was not expected to change significantly to increase the number of rooms used to sleep or huge number of deaths or out-migration occurring in the household within a year. Table 2 depicts the coding of household variables.

Table 2 : Coding of Household Level Variables

Number	Variable	Description	Code
1	Household wealth	Wealth quintile of the household serving as a proxy for household socio-economic status	[1] poorest; [2] poorer; [3] third; [4] second; [5] wealthiest
2	Crowding	Number of household members sleeping in a common room	Average number of household members per sleeping room

Source: Adjei (2019)

Community Level Variables

Community level variables that the study focused on were sanitation; time taken to reach water source and back; quality of water; poverty; proportion of females with secondary education or higher; ethnic heterogeneity (or ethnic fractionalisation) and nearest distance to a health facility.

Community Level Sanitation

Information regarding sanitation was captured in the household questionnaire. Household sources of sanitation were measured based on WHO/UNICEF definition for improved and unimproved sanitation (WHO/UNICEF, 2015). Improved sanitation includes the presence of toilets which were flush latrines/water closets and ventilated improved pit (VIP) or KVIP. Unimproved sanitation were categorised as toilets that were bucket latrines or faeces transferred elsewhere or defaecation in-house; open defaecation in the fields or bush; other pit latrines; and any other toilet of poor quality. Sanitation level within a community was measured as the proportion of households in a particular sub-district in a given year that had improved sanitation. Here, it means that all households within a particular sub-district in a given year (irrespective of being part of this study) were taken into consideration.

This variable was also similar for the previous and following year. Hereinafter, all variables with information captured in household socio-economic and demographic questionnaire had similar observations for previous and the following year. Time taken by members of households to reach water source is also a proxy for determining sanitation level (United Nations, 2014). Sanitary conditions are recognised to be poor if a household spent at least 30 minutes of round trip to reach water source and back (GSS, GHS & ICFI, 2015; United Nations, 2014). Hence, this study estimated the proportion of households in each community in a given year that used at least 30 minutes to reach the water source and back as a proxy for the level of sanitary conditions at the community level (The UN Special Rappoteur, 2014; GSS, GHS & ICFI, 2015). Time spent by households to fetch water from the water source was captured by the household form. Quality of water accessed by the community was also measured based on WHO/UNICEF definition for improved and unimproved water source (WHO/UNICEF, 2015). Information regarding the households' sources of water was recorded in the household questionnaire. Piped into dwelling, public tap, closed bore hole, closed well and rain water were regarded as improved sources of water in this study. Unimproved sources of water, however, include open well; stream or river; lake, dam or pond; water trucks; sachet water; bottled water; and any other sources of water. Improved quality of water (water safety) accessed at the community level was determined by proportion of all households within a particular sub-district in a given year with improved sources of water.

Community Level Poverty

Another independent variable at the community level in this study was poverty level in a particular community. Asset data captured by household form were used to construct wealth quintile for all the households in each sub-district in a given year. PCA was employed to construct the wealth quintile and households within the last two quintiles (poorest and poorer) were classified as poor. Hence, proportion of all poor households within a specific community in a given year was recognised as a measure of community poverty level.

Community Educational Level

The educational level of all individuals in the KHDSS area was captured in the education questionnaire which was administered to members of KHDSS every year. Adjei et al.'s study (2015) on abortion conducted in the study area revealed that the reproductive age group in the area includes 13-year old females. Therefore, the proportion of all females of age 13 years or above with at least secondary education in each sub-district within a given year was estimated and used as a proxy for literacy level for each sub-district (or community). This means that, a female in the study area has to be at least 13 years of age and must have educational level of secondary or above before being considered in the calculation.

Ethnic Heterogeneity

Ethnicity information was recorded in household questionnaire. Ethnicity of a child in the KHDSS area was determined by the ethnicity of the household head. The household head was either a female or male who was responsible for the child's upkeep. Hence, the household head had more influence on the up-bringing of the child and therefore the impact of cultural factors on neonates was likely to come from the household head's lineage. Since ethnicity is not likely to change overtime, previous and succeeding years having the same ethnicity is immaterial. The degree of ethnic heterogeneity (or fractionalisation) at the community level was measured using an index called ethno-linguistic fractionalisation (ELF). Ethnic ELF is defined as the probability that two individuals randomly selected from an area will belong to two different ethnic groups (Fearon, 2003; Posner, 2004). The theoretical value is zero when there is absolutely no fractionalization (or perfect ethnic homogeneity); and there is absolute fractionalisation (or absolute heterogeneity) when the theoretical value is one. In this study, "least fractionalised" sub-category were sub-districts with ELF between 0 and 0.19. Sub-districts with ELF between 0.2 and 0.58 were classified as "moderately fractionalised" whereas sub-districts having ELF in the range 0.59 – 1 were categorised as "highly fractionalised". All the categorisation done was based on literature (Fearon, 2003). In summary, ELF is a measure of ethnic diversity in a given area at a particular time.

Ethno-Linguistic Fractionalisation (ELF) Measure

ELF of the sub-districts within a given year was measured using the formula

$$ELF = 1 - \sum_{i=1}^{n} s_i^2$$

Where S_i is the share of the population in a particular sub-district in a given year denoted by S_1, S_2, S_3, …, S_n

Si in this study was calculated as a proportion of each ethnic group (i.e taking into consideration ethnicity of all household heads irrespective of being part of the study or not) within a specific sub-district in a given year.

In accordance with available literature, ELF in a given area varies over time (Posner, 2004). Hence, it was appropriate for using ELF since this study was longitudinal and therefore had the strength of accounting for this variation. Although the ELF is an index for ethnic diversity, it however has a limitation of recognising already amalgamated ethnic groups with two different cultures as similar (Posner, 2004). For example, in this study, amalgamated ethnic groups of Ga and Ewe (Table 3) which have completely different cultures were considered as similar ethnic group. However, the idea behind using ELF in this study is to look at the possible concentration of some ethnic groups in the sub-districts and subsequently generate hypothesis for further studies. Table 3 depicts the ethnic groups used for the calculation of ELF.

Table 3: Ethnic groups in the 12 sub-districts of the KHDSS area

Number	Ethnic Group
1	Akan
2	Bimoba/Chokosi
3	Dagarti/Frafra/Kusasi
4	Fulani
5	Ga/Ewe/Dambge
6	Sisala/Wala
7	Gonja/Dagomba/Mamprusi
8	Kokomba/Basare
9	Mo
10	Zambraba
11	Banda/Pantra
12	Other

Source: Adjei (2019)

Distance to the Nearest Health Facility

Distance to the nearest health facility was measured using GIS technique. Compounds of all households in the KHDSS area have been geocoded. Hence the nearest distance in kilometers from each household within a particular sub-district in a given year can be estimated. The average distance of all households to their nearest health facilities in a particular sub-district in each year was estimated from 2005 to 2014. The averages of the nearest distance in each year served as the community level variable for this study. Health facilities that were considered in this study were rural health clinics; CHPS compounds; health centres; maternity homes; and district and municipal hospitals. It was expected that most of the community members were more likely to access these health facilities for maternal and neonatal care services. These health facility records were accessed from DHIMS (District Health Information Management System) database of District

Health Directorates of both Kintampo North Municipality and South District. Other records that were accessed at the time when DHIMS was not in existence were accessed from hardcopy files. Quality control checks were done by randomly cross-checking about 20% of the hospital records with report of 2010 Ghana Population and Housing Census and databases of other studies that have been conducted by KHRC. Table 4 presents the coding of community level variables.

Table 4: Coding of Community Level Variables

Number	Variable	Description	Code
1	Sanitation	Sanitation at the community level	Proportion of households within a given community in each year that have improved sanitation
2	Travel time to water source	Time (in minutes) taken by community members to reach water source	Proportion of households in a given community per year that spent at least 30 minutes to travel to the water source and returned
3	Water safety	Level of water safety within a community	Proportion of households within a given community in each year that had access to improved water
4	Poverty	Poverty level within a given community	Proportion of the two lowest quintiles of total households within a given community in a given year
5	Community education	Level of female education within a community	Proportion of females in the community with secondary or higher education in a given year
6	Ethnic heterogeneity	Heterogeneity of ethnic groups within a given community in a specific year	[1] Least fractionalised; [2] Moderately fractionalised; [3] Highly fractionalised

Table 4 continued

7	Nearest health facility	Average distance of households (in kilometers) in a community to their nearest health facilities	Average of distances (in kilometers) from each household to its nearest health facility in a particular community in a given year

Source: Adjei (2019)

Determination of Causes of Deaths

Causes of neonatal deaths were determined by using a validated verbal autopsy (VA) tool with a sensitivity greater than 60% for all major causes. Specificity was found to be 76% for birth asphyxia and greater than 85% for prematurity and infection. (Edmond et al., 2008) The VA questionnaire had a battery of questions together with a narration section where the immediate caregiver of the neonates gave a vivid account of what might have led to the death of the neonate (Welaga et al., 2013). The VA interviews were conducted by well-trained field supervisors of KHRC and it was ensured that the interviews were conducted as closely as possible to the day of death to reduce recall bias. Because field supervisors training includes psychological aspect, they were able to handle emotional and psychological trauma during the interview. Data collection were rigorously supervised and 5% of the interviews were repeated to ensure data quality. In cases where discrepancies were detected, interviews were repeated. Three clinicians trained on coding of verbal autopsies reviewed the same VA questionnaire independently to assign the possible cause of death in accordance with 3-digit code of the International Statistical Classification of Diseases and Health-Related Problems (Owusu-Agyei et al., 2012; Welaga et al., 2013). The possible cause of neonatal death is established if there was concordance in the review diagnosis of at least two clinicians. In addition, VA questionnaires were submitted to two additional clinicians for review when there was discordance among all the first three clinicians. The cause of neonatal death was declared indeterminate where consensus could not be reached with regards to possible cause of death. Moreover, the possible cause of neonatal death was declared unknown where there was little or no information to account for possible causes of death.

Classification for Neonatal Causes of Death

Neonatal deaths were classified into six major categories namely congenital abnormality, prematurity, birth asphyxia, infection (sepsis, meningitis, pneumonia, septicaemia, tetanus, diarrhea and other neonatal infections), other specific causes of death (malaria, injury, infant haemorrhage and other specific causes excluding the first four major causes) and unexplained cause of death. This classification method was based on Neonatal and Intrauterine Death Classification according to Etiology (NICE) and the WHO Child Health Epidemiology Reference Group (CHERG) and has been described elsewhere (Edmond et al,, 2008). Table 5 depicts the classification of the six major categories. Hence the cause-specific neonatal deaths for this study were six.

Table 5: Classification of 6 major causes of death

Number	Neonatal death	Infant born alive and cried, moved or breathed after birth and then died within the first 28 days of life
1	Congenital abnormality	Neonatal death due to one or more of the following: Major or lethal congenital abnormality Unspecified; specific abnormality e.g neurological, neural tube defect
2	Prematurity	Neonatal death due to one or more of the following: Severe immaturity (<33 weeks), birthweight<1.8 kg where gestation is unknown, specific severe complications of prematurity such as surfactant deficiency or necrotising enterocolitis

Table 5 continued

3	Birth asphyxia	Neonatal death in an infant ≥33 weeks of gestation due to one or more of the following: Obstetric complications, maternal haemorrhage, or clinical diagnosis of birth asphyxia (no cry soon after birth plus either convulsion/spasms or not able to suckle normally after birth)
4	Infection	Neonatal death in an infant ≥33 weeks of gestation due to one or more of the following: Tetanus, meningitis, pneumonia, diarrheoa, septicaemia, other infection
5	Other	Neonatal death in an infant ≥33 weeks of gestation due to a cause not included in first 4 selected causes including: Accident/injury, infant haemorrhage respiratory distress syndrome, severe neonatal jaundice
6	Unexplained	Neonatal death due to unknown cause including sudden infant death syndrome

Source: Edmond (2008)

CHAPTER FIVE

STATISTICAL ANALYSES AND METHODOLOGICAL PROCEDURES

Introduction

This chapter describes the method of analysis for descriptive, inferential and spatial analyses components of this work. It also describes the methodological procedures or concepts underlying the inferential and spatial analyses.

Statistical Analysis

In analysing the data for this study, the descriptive analysis was first done to describe the general characteristics of the study population and percentage distribution of neonatal deaths to give a detailed description of the data. This was followed by risk analysis of deaths within the first 28 days of neonatal life. Inferential statistical techniques were thereafter used to address the second objective of the study. The final analysis involved spatial analysis used to address the third and fourth objectives.

Descriptive Statistical Analysis

The distribution of individual, household and community level variables was presented to give a comprehensive view of the study population. Categorical variables were expressed in percentages together with their corresponding numbers. On the contrary, continuous variables that were normally distributed were expressed in means and the standard deviation reported. Proportions of neonatal deaths across subgroups of all the independent variables considered in the study were also reported.

Risk Analysis of Neonatal Deaths in First 28 Days

Objective 1 of this study was to analyse survival experience of neonates in the KHDSS area within the first 28 days. This was addressed by estimating the risk of neonates (incidence rates) dying in each day within the first 28 days. The risk was expressed in deaths per person-days and 95% confidence intervals for risk of neonatal death for specific days were also estimated. Graphs depicting risk of death on each day and corresponding 95% confidence intervals were provided to depict the risk of mortality. Stata 14.0 software was used for this analysis.

Inferential Statistical Analysis

The objective two of the study focused on the influence of individual, household and community level factors on neonatal mortality. This was addressed by employing multilevel cox proportional hazard model with individual level variables (level 1) nested in household level variables (level 2) and household level variables in turn nested in community level variables (level 3). The multilevel cox model was constructed by hierarchically introducing the covariates. The individual level variables were first used to construct the standard cox proportional hazard model (Model I) to assess risk factors of neonatal mortality. The second model (Model II) consists of the individual level variables in addition to household level variables with household specific frailty term. Frailty is simply an unobserved effect due to a group (for example household or a community). Hence, household-specific frailty is simply the unobserved effect of the household on neonatal mortality. For example, this study did not measure genetic factors so unobserved effect (i.e frailty) at the household level could be due to differential risk in genetic factors. The third model (model III) was constructed by adding the community level variables with community-specific frailty to the individual and household level variables. Scaled Schoenfeld residuals test was used to assess the proportional hazards assumption for all the independent variables used for the multilevel cox regression. This test assessed whether the scaled Schoenfeld residuals of the regression parameters varied with the analysis time (Grambsch & Therneau, 1994). The standard errors of the final model was found to be robust when the variables that violated the assumption were included in the model (Lin & Wei, 1989). Therefore the average effect of these variables over the study period was reported (Lin & Wei, 1989). In addition to scaled Schoenfeld residuals test, Kaplan-Meier observed survival curves and cox predicted curves for each categorical covariate were compared and subsequently assessed for proportional hazards assumption. Scaled Schoenfeld residuals test for proportional hazards assumptions conducted for each covariate and graphs depicting plots of Kaplan-Meier observed survival curves and cox predicted curves have been depicted in Appendix I. Robust standard errors for the final model have also been presented in Appendix II.

Another multilevel cox proportional hazard model was also built by assessing clustering effect at the household and adjusting for individual and community level variables (Module IV). The Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) values calculated for each model were used to assess the models goodness of fit. Since lower AIC and BIC values produce better models, Model II should have been the best model. However, Model II did not have the full complement (or full set) of the covariates so Model IV which had the full complement and lower AIC and BIC values as compared to Model III (which also had the full complement) was chosen as the final model. Although Model III and Model IV had the full complement of the covariates, frailty parameters of Models III and IV were communities and households respectively. All statistical tests were two-tailed and p-values less than 0.05 were considered to be statistically significant. Stata 14.0 and R software were used for the analysis.

Spatial Analysis for All-Cause Neonatal Mortality

The third objective was to assess the spatial clustering of all-cause neonatal mortality at the KHDSS area. This was addressed by using the spatial scan statistic with the aid of the SaTScan software to identify the clustering of all-cause neonatal mortality in the KHDSS area. The SaTScan identified a cluster of any size in any geographic location up to a maximum size to reduce the problem of multiple statistical tests. Poisson model was employed to run a purely spatial analysis scanning for clusters (village or group of villages) with high rates of all-cause neonatal mortality. Scanning was set to identify villages with high proportion of all-cause neonatal deaths because the interest was to search for village or a group of villages with proportion of all-cause neonatal mortality that was higher than average. Geographic overlap was not considered in the setting; therefore secondary clusters did not overlap the most significant (or likely) cluster. Maximum cluster size was set to 50% of the total population at risk in order to scan for small to large clusters. In order to ensure sufficient statistical power, the number of Monte Carlo replications was set to 999 and clusters with $p<0.05$ were considered as statistically significant.

Spatial Analysis for Cause-Specific Neonatal Mortality

The fourth objective of this study assessed the spatial clustering of cause-specific neonatal mortality in the KHDSS area (or the Kintampo Districts). This objective was addressed by using the Bernoulli model of the purely spatial scan statistic. The operational definition of cases was all neonatal deaths that were caused by a specific morbidity. Controls were all other deaths caused by other morbidities together with other neonates who were alive. The setting and the procedure used for identifying the most likely and secondary clusters were the same for the Poisson model except that the cases change depending on the morbidity attributable to the neonatal mortality.

Methodological Procedure

This section focused on the explanation of the methodological procedure underlying the inferential and spatial analyses components of this work.

Multilevel Cox Proportional Hazard Models: Methodological Procedure

The survival analysis technique used to analyse the study data was the multilevel cox proportional hazard model. Cox proportional hazard models are used to analyse survival data usually with right censored observations. Right censoring occurs when observation is terminated before an individual experience the event (Allison, 2014). Cox proportional models are semi-parametric models which are generally used to model hazard and survival functions. It is usually parametric in the sense of using parametric methods in its regression (i.e proportional hazard assumption) but non-parametric in the sense of having no underlying assumption for probability distribution of its time to an event. The model assumes that effect of covariates are constant over time (Allison, 2014). In effect the ratio of the hazard due to an exposed group to an unexposed group is constant at any time t throughout the study period (i.e $h(t|X_1)/h(t|X_0)$ = Constant). The hazard is the instantaneous potential per unit time for the individual to experience the event, on condition that the individual has survived up to the time t. Mathematically, the hazard is defined as

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t + \Delta t \mid T \geq t)}{\Delta t}$$

Where P=Probability; T=Individual's survival time

The numerator can be expressed as

$P(t \leq T < t + \Delta t | T \geq t)$=P(Individuals fails in the interval $[t, t + \Delta t]$|survival up to time t)

Given a set of covariates X_i, the cox proportional hazard model assumes that the hazard is proportional to an unspecified baseline hazard but influenced by a parameterized function of the set of covariates (Cox, 1972). This model has a strength in its ability to leave the baseline hazard unspecified and therefore not depending on any parametric distribution which may be difficult to identify. Mathematically, given the set of covariates X_i, the general form of the cox proportional hazard is given by

$$h(t|X_i)=h_0(t)e^{\beta X_i} \quad \text{--(1)}$$

Where i=1,2,….,k

Let N be the total number of neonates in the dataset over the 10-year study period with each neonate in a given household found in a given community (or sub-district). Let G denotes the total number of households or communities over the 10-year period such that given the i-th household or community which consist of n_i neonates, we have

$$\sum_{i=1}^{G} n_i = N$$

Hence for a j-th neonate in the i-th household or community, the cox proportional hazard model is given by

$$h(t|X_{ij})=h_0\alpha_i(t)e^{\beta X_{ij}} \quad \text{---(2)}$$

Where α_i is the frailty at the i-th household or community. Frailties are unobservable positive quantities which are assumed to have mean 1 and variance θ which is estimated from the data (Stata Manual, 2014). Shared-frailties are used to model within-group correlations and observations within the same group are said to be correlated if they shared the same frailty. Therefore an estimate of θ is a measure of the degree of correlation within a i-th household or community (Stata Manual, 2014). Hence when θ=0, the shared-frailty model reduces to the standard cox proportional hazard model.

For $v_i = \log\alpha_i$, the frailty-model in (2) can be expressed as

$$h(t|X_{ij})=h_0(t)e^{(\beta X_{ij} + v_i)} \quad \text{---(3)}$$

Therefore, the log frailties v_i become analogous to random effects in standard linear models (Stata Manual, 2014). In this study, the frailty is assumed to follow a gamma distribution because of two reasons. Firstly, the available evidence shows that the choice of frailty distribution is not likely to be sensitive to the results of hazard models (Gyimah, 2001; Omarabad, 2004; Sastry, 1996). Secondly, the analytical tractability and flexibility in gamma distribution makes it suitable for the frailty in this study (Sastry, 1996).

Spatial Analysis for mortality clustering: Methodological Procedure

This method referred to as Kulldorf method is a standard purely spatial scan statistic that imposes a circular window on the map. This window is centred on several possible grid point positioned throughout the study region. The radius of the circle varies continuously in size from zero to some upper limit specified by the user for each grid point. The circular window is therefore flexible in both size and location. In a nutshell, this method creates an infinite number of distinct geographical circles with different sets of neighbouring locations within them. Each circle is a potential candidate cluster. The grid points can also be identical to coordinates of a location.

The significance of a cluster is determined by a likelihood ratio test. For each location and size of the window, the alternative hypothesis for this test is that there is an elevated risk within the window as compared to outside. Based on the Poisson assumption, the likelihood function for a specific window is proportional to 1. The likelihood function is given by

$$\left(\frac{c}{E[c]}\right)^{c}\left(\frac{C-c}{C-E[c]}\right)^{C-c} I()$$

Where C = Total number of cases; c = The observed number of cases within the window;

E[c] = The covariate adjusted expected number of cases within the window under the null-hypothesis; and I() = Indicator function.

Since the analysis is conditioned on the total number of cases observed, C-E[c] is the expected number of cases outside the window. When SaTScan is set to scan only for clusters with high rates, I() is equal to 1 when the window has more cases than expected under the null-hypothesis, and 0 otherwise. The opposite is true when SaTScan is set to scan only for clusters with low rates. When the program scans for clusters with either high or low rates, then I()=1 for all windows. However, the Bernoulli likelihood function is given by

$$\left(\frac{c}{n}\right)^{c}\left(\frac{n-c}{n}\right)^{n-c}\left(\frac{C-c}{N-n}\right)^{C-c}\left(\frac{(N-n)-(C-c)}{N-n}\right)^{(N-n)-(C-c)} I()$$

Where C and c are defined as above. n = total number of cases and controls in a window while

N = Combined total number of cases and controls in the dataset.

For all window locations and sizes, the likelihood function is maximized and the one with the maximum likelihood constitutes the most likely cluster. This is recognised as the cluster that is least likely to have occurred by chance. The likelihood ratio for this window constitutes the maximum likelihood ratio test statistic. Its distribution under the null-hypothesis is obtained by performing the same analytic exercise repeatedly on a large number of random replications of the dataset. The p-value is obtained through Monte Carlo hypothesis testing, by comparing the rank of the maximum likelihood from the real dataset with the maximum likelihoods from the simulated (or random) datasets. If this rank is R, then p = R / (1 + #simulation). Where #simulation is the number of simulations. To make the estimation of p tractable, the number of simulations is restricted to 999 or some other number ending in 999 such as 1999, 9999 or 99999. This makes it clear as to whether to reject the null hypothesis at the traditional significance levels of 0.05 or 0.01.

For purely spatial analysis, SaTScan also identifies secondary clusters in the dataset in addition to most likely cluster and orders them according to their likelihood ratio test statistic. Geographically overlapping clusters are not reported by default in SaTScan. Hence, secondary clusters that do not overlap spatially with the most likely cluster are reported. Since these secondary clusters may be of great interest, they are always reported.

CHAPTER SIX

RESULTS OF MORTALITY RISK ANALYSIS AMONG NEONATES

General Characteristics and Distribution of Neonatal Deaths by Individual, Household and Community Level Characteristics

Table 6 presents the general characteristics of neonates and also the distribution of neonatal deaths by individual, household and community level characteristics.

General Characteristics of Neonates

Regarding general characteristics of neonates, male neonates (51.1%) were slightly more than the female neonates (48.9%). Neonates whose mothers did not have formal education were more than half (55.5%) and constitute the highest proportion. However, neonates born to mothers with secondary education or above (3.7%) constitute the least proportion. Almost seven out of every 10 (69.6%) neonates were born to mothers who received tetanus toxoid injection during pregnancy. Highest proportion (67.8%) of the neonates had mothers who delivered between the ages 20 and 34 years. Approximately 12% (12.4%) of neonates had mothers who were teenagers (<20 years) at the time of delivery. Neonates whose mothers had previous adverse pregnancy constitute 11.7%. Approximately 47% (47.4%) of the neonates were delivered at home whereas more than one-third (34.3%) of them were delivered at the hospital.

With regards to household level characteristics, neonates born into households with second wealth quintile (20.8%) had the highest proportion. This was followed by neonates in the wealthiest household quintile (20.5%). On the average there were 2.8 persons per sleeping room (Standard deviation=1.4 persons per sleeping room) in the households of neonates.

Regarding community level characteristics, the highest proportion (90.4%) of neonates belonged to communities which were highly fractionalised. On the average, the distance to the nearest health facilities was 1.6 km (Standard deviation=0.9 km). Community educational level was found to be 3.8% (Standard deviation=1.7%) on the average. In addition, poverty level in the communities were found to be 41.1% (Standard deviation=2.2 %) on the average.

Distribution of Neonatal Deaths by Individual, Household and Community Level Characteristics

Regarding distribution of neonatal deaths, proportion of neonatal deaths among males (2.6%) was higher than that of the females (1.6%). Also, neonates with birth order 1 (2.6%) had the highest proportion of deaths whereas neonates with birth order 4 or above (1.9%) had the least proportion of deaths. Neonates born to mothers with secondary education or above had the least proportion of deaths (0.9%) while neonates whose mothers had Middle, Junior High or Junior Secondary School (2.6%) had the highest proportion of deaths. However, neonates born to mothers without formal education had 1.9% deaths. Proportion of neonatal deaths among mothers who did not receive tetanus toxoid injection (2.3%) was slightly higher than neonatal deaths among mothers who received tetanus toxoid injection (2.0%). Compared with neonates born to multi-parae of 2-4 (2.0%) and 5 or above (2.0%) respectively, neonates born to primi-parae (2.0%) had the highest proportion of deaths.

Table 6 : General characteristics and deaths by individual, household and community level characteristics

Variable		Neonatal deaths		Total
		Yes	No	
Individual variables	n (%)	n (%)	n (%)	N (%)
Sex				
Male	15406 (51.1)	395 (2.6)	15011 (97.4)	15406 (100.0)
Female	14487 (48.9)	239 (1.6)	14487 (98.4)	14487 (100.0)
Total	29893 (100.0)			
Birth order				
1	7105 (23.6)	181 (2.6)	6924 (97.4)	7105 (100.0)
2-3	10008 (33.2)	205 (2.1)	9803 (97.9)	10008 (100.0)
≥4	12994 43.2)	247 (1.9)	12747 (98.1)	12994(100.0)
Total	30107 (100.0)			
Educational level				
None	16649 (55.5)	317 (1.9)	16332 (98.1)	16649 (100.0)
Primary	6562 (21.9)	154 (2.3)	6408 (97.7)	6562 (100.0)
Middle/JHS/JSS	5705 (19.0)	151 (2.6)	5554 (97.4)	5705 (100.0)
Secondary or above	1108 (3.7)	10 (0.9)	1093 (99.1)	1108 (100.0)
Total	30024 (100.0)			
Tetanus toxoid				
Yes	20456 (69.6)	415 (2.0)	20041 (98.0)	20456 (100.0)
No	8936 (30.4)	205 (2.3)	8731 (97.7)	8936 (100.0)
Total	29392 (100.00			
Gravidity				
1	6529 (21.7)	167 (2.6)	6362 (97.4)	6529 (100.0)
2-4	13998 (46.4)	275 (2.0)	13723 (98.0)	13998 (100.0)
≥ 5	9601 (31.9)	192 (2.0)	9409 (98.0)	9601 (100.0)
Total	30128 (100.0)			
Maternal age at delivery				
<20	3715 (12.4)	90 (2.4)	3625 (97.6)	3715 (100.0)
20-34	20361 (67.8)	414 (2.0)	19947 (98.0)	20361 (100.0)
35+	5958 (19.8)	130 (2.2)	5828 (97.8)	5958 (100.0)
Total	30034 (100.0)			
Previous adverse pregnancies				
Yes	3512 (11.7)	91 (2.6)	3421 (97.4)	3512 (100.0)
No	26613 (88.3)	543 (2.0)	26070 (98.0)	26613 (100.0)
Total	30125 (100.0)			
Place of delivery				
Hospital	10348 (34.3)	296 (2.9)	10052 (97.1)	10348 (100.0)
Health Centre/Clinic	2611 (8.7)	39 (1.5)	2572 (98.5)	2611 (100.0)

Table 6 continued

Private maternity home	2244 (7.5)	35 (1.6)	2209 (98.4)	2244 (100.0)
TBA's house	483 (1.6)	12 (2.5)	471 (97.5)	483 (100.0)
At home	14296 (47.4)	246 (1.7)	14050 (98.3)	14296 (100.0)
Other	150 (0.5)	6 (4.0)	144 (96.0)	150 (100.0)
Total	30132 (100.00)			
Gestational age	Mean (SD)	Mean (SD)	Mean (SD)	
	38.2 (4.2)	36.3 (5.2)	38.3 (4.2)	25150 (100.0)
Household variables				
		Yes	No	**Total**
	n (%)	n (%)	n (%)	
Household wealth				N (%)
Poorest	5703 (18.9)	124 (2.2)	5579 (97.8)	5703 (100.0)
Poorer	5887 (19.6)	123 (2.1)	5764 (97.9)	5887 (100.0)
Third	6099 (20.2)	113 (1.9)	5986 (98.1)	6099 (100.0)
Second	6275 (20.8)	129 (2.1)	6146 (97.9)	6275 (100.0)
Wealthiest	6168 (20.5)	145 (2.3)	6023 (97.7)	6168 (100.0)
Total	30132 (100.0)			
Crowding	Mean (SD)	Mean (SD)	Mean (SD)	
	2.8 (1.4)	2.8 (1.4)	3.1 (1.5)	30062 (100.0)
Community variables				
Ethnic heterogeneity				
Least fractionalised	879 (2.9)	22 (2.5)	857 (97.5)	879 (100.0)
Moderately fractionalised	2012 (6.7)	33 (1.6)	1979 (98.4)	2012 (100.0)
Highly fractionalised	27241 (90.4)	579 (2.1)	26662 (97.9)	27241 (100.0)
Total	30132 (100.0)			
	Mean (SD)	Mean (SD)	Mean (SD)	
Average distance to the nearest health facility	1.6 (0.9)	1.6 (1.0)	1.6 (0.9)	30132 (100.0)
Average travel time to water source	17.8 (14.7)	17.7 (13.8)	17.8 (14.7)	30132 (100.0)
Poverty	41.1 (2.2)	41.2 (2.2)	41.1 (2.1)	30132 (100.0)
Sanitation	28.6 (24.3)	28.2 (24.4)	28.8 (24.3)	30132 (100.0)
Water safety	62.5 (19.9)	63.4 (18.2)	62.5 (19.9)	30132 (100.0)
Community education	3.8 (1.7)	3.9 (1.6)	3.8 (1.7)	30132 (100.0)

Source: Adjei (2019)

Additionally, highest proportion of neonatal deaths was among neonates born to mothers who were teenagers (2.4%). Among neonates belonging to mothers who had previous adverse pregnancies (foetal deaths constituting miscarriages, stillbirths or ectopic), a proportion of 2.6% died in comparison with 2.0% deaths among neonates whose mothers did not experience any previous adverse pregnancies. In addition, the highest proportion (4.0%) of neonatal deaths occurred among neonates belonging to mothers who delivered at other places (e.g mothers who were on their way to the hospital when they delivered) and this was followed by 2.9% deaths that occurred among neonates whose mothers delivered at the hospital. The least proportion of deaths occurred among neonates belonging to mothers who delivered at the health centres or clinics (1.5%). Neonates who died had a mean gestation period of 36.3 weeks (Standard deviation=5.2 weeks) as compared to mean gestation period of 38.3 weeks (Standard deviation=4.2 weeks) among neonates who were alive throughout the neonatal period.

Regarding the distribution of neonatal deaths by household level factors, there were slight differences in proportion of neonatal deaths among the various levels of the household wealth. However, neonates belonging to the wealthiest household (2.3%) had the highest proportion of deaths whereas the least proportion of deaths was among neonates belonging to the third household quintile (1.9%). The mean crowding index was larger among neonates who were alive (3.1 persons per sleeping room [Standard deviation=1.5 persons per sleeping room]) than among neonates who died (2.8 persons per sleeping room [Standard deviation=1.4 persons per sleeping room]).

With regards to distribution of neonatal deaths at the community level, the least fractionalised (2.5%) communities had the highest proportion of neonatal deaths in comparison with the moderately (1.6%) and highly fractionalised (2.1%) communities. Among neonates who died, the average distance to the nearest health facilities in their communities was 1.6 km (Standard deviation=1.0 km) while that of neonates who were alive was also 1.6 km (Standard deviation=0.9 km). There was slight difference in average proportion of a round trip of 30 minutes or more to water source and back among neonates who died (17.7 % [Standard deviation=13.8 %) and neonates who were alive (17.8% [Standard deviation=14.7%]). Among neonates who died, their community poverty level (41.2% [Standard deviation=2.2%]) was a little bit higher than that of those who were alive (41.1% [Standard deviation=2.1%]). Additionally, improved community sanitation level among neonates who were alive (28.8% [Standard deviation=24.3%]) was higher than the improved community sanitation level among neonatal deaths (28.2% [Standard deviation=24.4%]). Paradoxically, the level of community improved source of drinking water (safe water) among neonatal deaths (63.4% [Standard deviation=18.2%]) was higher than that of the neonates who were alive (62.5% [Standard deviation=19.9%]). Proportion of community education was slightly higher among neonates who died (3.9% [Standard deviation=1.6%]) than among neonates who were alive (3.8% [Standard deviation=1.7%]).

Risk of Death among Neonates in the first 28 days of life

Figure 8 depicts the pattern for risk of neonatal deaths and the corresponding 95% confidence intervals within the first 28 days in the Kintampo

Districts. The risk of neonatal deaths was estimated as the number of deaths per the total person-days (sum of the person days contributed by each neonate). Since the calculation is based on the assumption that on day 1 none of the neonates had contributed any person-day, neonatal deaths on day 1 (15 deaths) was combined with deaths in day 2 (44 deaths) and the risk of neonatal deaths estimated on day 2.

The highest risk of death in the Kintampo Districts was 1057 deaths per 100,000 person-days (95% CI: 947.37-1180.26) and that occurred on day 3. This was followed by day 2 (195.8 deaths per 100,000 person-days, 95% CI: 151.71-252.72) and day 4 risk (188.2 deaths per 100,000 person-days, 95% CI: 144.84 - 244.55) respectively. The fourth highest risk was on day 8 (77.6 deaths per 100,000 person- days, 95% CI: 51.56 -116.76) and the fifth highest risk was a tie on day 5 and 6 respectively with a risk of 64.0 deaths per 100,000 person-days (95% CI: 40.81-100.30). The least risk was 6.8 deaths per 100,000 person-days (95% CI: 1.69 - 27.06) and that occurred on days 17 and 18.

Regarding the pattern of neonatal mortality risk, the risk of neonatal deaths increased immensely from day 2 to day 3 and declined sharply on day 4. It continued to decline up to day 5 and almost plateaued from day 5 to day 7. There was a slight increase in risk from day 7 to day 8 and a decline from day 8 to day 9. The risk of death almost plateaued from day 9 to day 28.

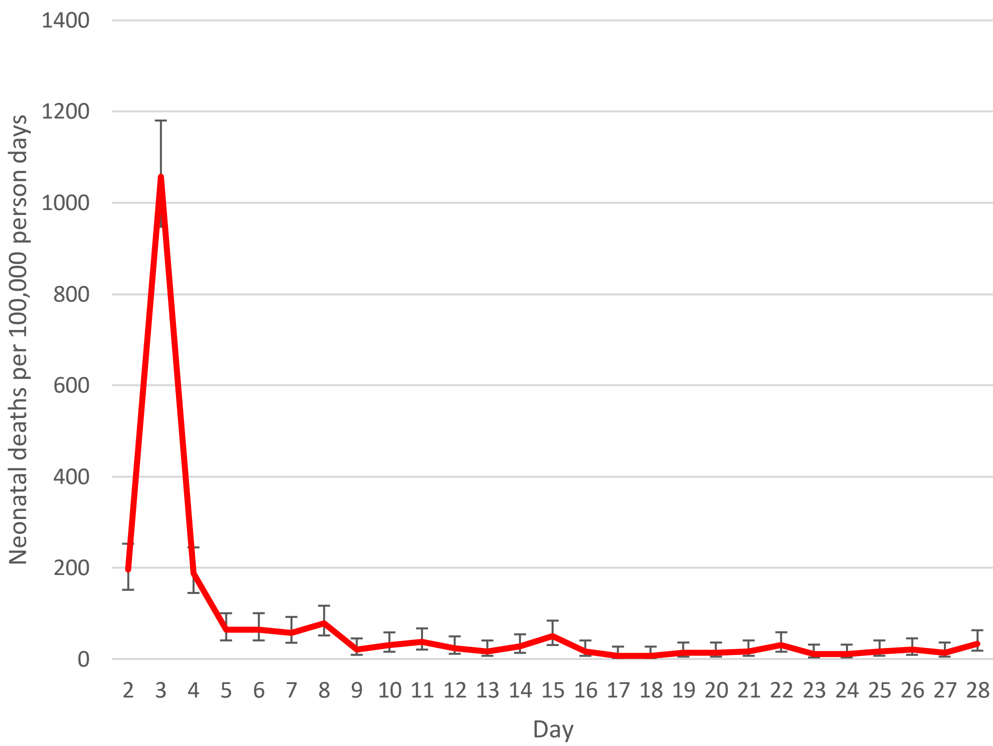


Figure 8 : Risk of neonatal deaths in the Kintampo Districts (2005-2014)

Source: Adjei (2019)

Multi-Level Regression Results

Model I results

Model I assessed the effect of only individual level covariates on the risk of neonatal mortality (Table 7). Sex of neonates was a significant risk factor for neonatal mortality as females were 39% less likely to die as compared to the males (aHR=0.61, 95% CI: 0.51-0.73). Educational level of the mothers of neonates also had a statistically significant influence on the risk of neonatal mortality (Likelihood ratio p-value=0.0003). Neonates born to women with middle, JHS or JSS educational level had 30% excess risk of mortality as compared to neonates whose mothers did not have any formal education (aHR=1.30, 95% CI: 1.03-1.63). On the contrary, neonates belonging to mothers with secondary or higher level of education had 63% less risk of mortality as compared to neonates whose mothers did not have any formal education (aHR=0.37, 95% CI: 0.18-0.76). Tetanus toxoid status of mothers of the neonates were found to be a risk factor for neonatal mortality. Neonates born to mothers who did not receive tetanus toxoid injection during pregnancy were 1.3 times more likely to die as compared to neonates belonging to mothers who received tetanus toxoid injection during pregnancy (aHR=1.30, 95% CI: 1.07-1.57). Neonates whose mothers had previous adverse pregnancy had increased risk of mortality (aHR=1.37, 95% CI: 1.04-1.80) in comparison with neonates whose mothers did not have any previous adverse pregnancy. Additionally, place of delivery was a risk factor for neonatal mortality (Likelihood ratio p-value<0.001). Neonates who were delivered at health centre/clinic (aHR=0.41, 95% CI: 0.27-0.61), private maternity home (aHR=0.46, 95% CI: 0.31-0.69) and at home (aHR=0.59, 95% CI: 0.48-0.72) had on the average 59%, 54% and 41% less risk of mortality respectively as compared to neonates delivered at the hospital. Gestational age of neonates also had significant effect on neonatal mortality as a week increase in age of neonates decreased his or her risk of mortality by 5% (aHR=0.95, 95% CI: 0.94-0.97). However, the individual level variables birth order (Likelihood ratio p-value=0.199), gravidity (Likelihood ratio p-value=0.445) and maternal age at delivery (Likelihood ratio p-value=0.469) did not have any statistically significant relationship with the risk of neonatal mortality.

Table 7: Relationship between neonatal deaths and individual, household and community factors in the Kintampo Districts

Variable	Model I aHR (95% CI)	Model II aHR (95% CI)	Model III aHR (95% CI)	Model IV aHR (95% CI)
Sex*				
Male	1	1	1	1
Female	0.61 (0.51-0.73)	0.61 (0.51-0.73)	0.61 (0.51-0.73)	0.61 (0.51-0.73)
Birth order				
1	1	1	1	1
2-3	1.23 (0.66-2.27)	1.26 (0.68-2.36)	1.27 (0.69-2.35)	1.27 (0.68-2.36)
≥4	0.93 (0.48-1.82)	0.99 (0.50-1.95)	0.98 (0.50-1.92)	0.98 (0.50-1.92)
Educational level*				
None	1	1	1	1
Primary	1.17 (0.94-1.47)	1.20 (0.95-1.50)	1.19 (0.95-1.50)	1.19 (0.95-1.50)
Middle/JHS/JSS	1.30 (1.03-1.63)	1.30 (1.03-1.65)	1.30 (1.02-1.64)	1.30 (1.02-1.65)
Secondary or above	0.37 (0.18-0.76)	0.35 (0.17-0.73)	0.37 (0.18-0.76)	0.37 (0.18-0.75)
Tetanus toxoid*				
Yes	1	1	1	1
No	1.30 (1.07-1.57)	1.30 (1.07-1.58)	1.32 (1.09-1.61)	1.32 (1.08-1.60)
Gravidity				
1	1	1		1
2-4	0.69 (0.37-1.28)	0.68 (0.36-1.29)	0.68 (0.36-1.27)	0.68 (0.36-1.27)
≥ 5	0.72 (0.35-1.49)	0.73 (0.35-1.52)	0.72 (0.35-1.49)	0.72 (0.35-1.49)

Table 7 Continued

Maternal age at delivery				
<20	1	1	1	1
20-34	1.06 (0.80-1.43)	1.04 (0.77-1.41)	1.06 (0.79-1.43)	1.07 (0.79-1.44)
35+	1.25 (0.84-1.85)	1.22 (0.82-1.83)	1.25 (0.84-1.86)	1.26 (0.84-1.88)
Previous adverse pregnancies*				
Yes	1.37 (1.04-1.80)	1.37 (1.04-1.81)	1.39 (1.05-1.82)	1.38 (1.05-1.83)
No	1	1	1	1
Place of delivery*				
Hospital	1	1	1	1
Health Centre/Clinic	0.41 (0.27-0.61)	0.40 (0.27-0.61)	0.40 (0.26-0.60)	0.40 (0.26-0.60)
Private maternity home	0.46 (0.31-0.69)	0.46 (0.30-0.68)	0.45 (0.30-0.68)	0.45 (0.30-0.68)
TBA's house	0.69 (0.33-1.48)	0.68 (0.32-1.46)	0.70 (0.33-1.50)	0.69 (0.32-1.49)
At home	0.59 (0.48-0.72)	0.59 (0.48-0.72)	0.57 (0.46-0.70)	0.56 (0.45-0.70)
Other	1.07 (0.40-2.88)	1.05 (0.39-2.86)	1.00 (0.37-2.70)	1.01 (0.37-2.73)
Gestational age*	0.95 (0.94-0.97)	0.95 (0.94-0.97)	0.95 (0.94-0.97)	0.95 (0.94-0.97)

Table 7 continued

Household wealth*			
Poorest	1	1	1
Poorer	0.86 (0.65-1.14)	0.86 (0.65-1.14)	0.86 (0.65-1.14)
Third	0.69 (0.51-0.92)	0.70 (0.52-0.94)	0.70 (0.52-0.94)
Second	0.89 (0.67-1.16)	0.91 (0.69-1.19)	0.90 (0.69-1.19)
Wealthiest	1.04 (0.80-1.36)	1.07 (0.82-1.40)	1.07 (0.82-1.40)
Crowding*	0.90 (0.84-0.96)	0.90 (0.85-0.97)	0.91 (0.85-0.97)
Ethnic heterogeneity			
Least fractionalised		1	1
Moderately fractionalised		0.96 (0.49-1.89)	0.96 (0.48-1.90)
Highly fractionalised		1.07 (0.60-1.90)	1.06 (0.59-1.91)
Distance to nearest health facility		1.02 (0.90-1.15)	1.02 (0.90-1.15)
Travel time to water source		1.00 (0.99-1.01)	1.00 (0.99-1.01)
Poverty		1.04 (0.99-1.08)	1.04 (0.99-1.08)

Table 7 continued

Sanitation			0.99 (0.98-1.00)	0.99 (0.98-1.00)
Water safety			1.00 (0.99-1.01)	1.00 (0.99-1.01)
Community education			1.05 (0.94-1.18)	1.05 (0.94-1.18)
Household frailty variance (p-value)		0.69 (0.52)		0.52 (0.48)
Community frailty variance (p-value)			$5x10^{-7}$ (0.89)	
AIC	10265.77	9674.08	10203.26	9772.61
BIC	10342.09	9678.23	10207.50	9776.77

AIC= Akaike information criterion BIC=Bayesian information criterion
aHR= Adjusted hazard ratio
*Likelihood ratio p-value (3 or more categories)<0.05
*p-value (Only 2 categories)<0.05

Source: Adjei (2019)

Model II results

In Model II, the impact of individual and household level covariates on the risk of neonatal mortality was analysed (Table 7). Sex of neonates was found to be a statistically significant risk factor for neonatal mortality. Females had 39% decreased likelihood of mortality as compared to males (aHR=0.61, 95% CI: 0.51-0.73). Educational level of the neonates' mothers had a statistically significant effect on the risk of neonatal mortality (Likelihood ratio p-value=0.0001). Neonates born to women with middle, JHS or JSS educational level were 30% more likely to die as compared to neonates whose mothers did not have any formal education (aHR=1.30, 95% CI: 1.03-1.65).

However, neonates born to women with secondary or higher level of education had 65% less risk of mortality as compared to neonates whose mothers did not have any formal education (aHR=0.35, 95% CI: 0.17-0.73). Neonates whose mothers had no tetanus toxoid vaccine during pregnancy were 1.3 times more likely to die as compared to those whose mothers received the vaccine during pregnancy (aHR=1.30, 95% CI: 1.07-1.58). In addition, neonates belonging to mothers who had previous adverse pregnancy had 37% excess risk of mortality (aHR=1.37, 95% CI: 1.04-1.81). Place of delivery was also a statistically significant risk factor for neonatal mortality (Likelihood ratio p-value<0.001). In comparison with neonates who were delivered at the hospital, neonates who were delivered at health centre/clinic (aHR=0.40, 95% CI: 0.27-0.61), private maternity home (aHR=0.46, 95% CI: 0.30-0.68) and at home (aHR=0.59, 95% CI: 0.48-0.72) had on the average 60%, 54% and 41% less risk of mortality. Gestational age of neonates was also found to be a statistically significant risk factor for neonatal mortality. A week increase in the gestational age of neonates decreased their risk of mortality by 5% (aHR=0.95, 95% CI: 0.94-0.97). Household wealth of neonates had a significant impact on neonatal mortality (Likelihood ratio p-value=0.039). Neonates in the third household wealth quintile were 31% less likely to die as compared to those in the poorest household quintile (aHR=0.69, 95% CI: 0.51-0.92). Moreover, for a unit increase in the crowded index, neonates had a 10% decreased likelihood of mortality (aHR=0.90, 95% CI: 0.84-0.96). However, the individual level variables birth order (Likelihood ratio p-value=0.269), gravidity (Likelihood ratio p-value=0.422) and maternal age at delivery (Likelihood ratio p-value=0.523) were not statistically significant risk factors of neonatal mortality. In addition, the variance of the household frailty term was found to be 0.69 but was not statistically significant (ɵ=0.69, p-value=0.52). This was an evidence that there was no unobserved heterogeneity at the household level. Hence, it can not be asserted that there were other factors affecting neonatal mortality at the household level that could not be explained by the covariates (or variables) included in the model.

Model III Results

Model III was a multilevel cox frailty model constructed to establish the relationship between individual, household and community level variables and the risk of neonatal mortality (Table 7). Sex of neonates had a significant impact on neonatal mortality as females had 39% less risk of mortality as compared to males (aHR=0.61, 95% CI: 0.51-0.73). Also, maternal level of education had a statistically significant effect on the risk of neonatal mortality (Likelihood ratio p-value=0.0002). Neonates whose mothers had middle, JHS or JSS educational level had 30% excess risk of mortality as compared to neonates whose mothers did not have any formal education (aHR=1.30, 95% CI: 1.02-1.64). On the other hand, neonates born to women with secondary or higher level of education had 63% less risk of mortality as compared to neonates whose mothers had no formal education (aHR=0.37, 95% CI: 0.18-0.76). Neonates whose mothers did not receive tetanus toxoid vaccine during pregnancy had 32% excess risk of mortality as compared to neonates whose mothers received the vaccine during pregnancy (aHR=1.32, 95% CI: 1.09-1.61).

Moreso, neonates belonging to mothers who had previous adverse pregnancy had 39% excess risk of mortality as compared to those whose mothers had no previous adverse pregnancy (aHR=1.39, 95% CI: 1.05-1.83). Place of delivery was found to be a risk factor for neonatal mortality (Likelihood ratio p-value<0.001). Neonates who were delivered at health centre/clinic (aHR=0.40, 95% CI: 0.26-0.60), private maternity home (aHR=0.45, 95% CI: 0.30-0.68) and at home (aHR=0.57, 95% CI: 0.46-0.70) had on the average 60%, 55% and 43% less risk of mortality as compared to those delivered in the hospital. For a week increase in the gestational age of neonates, the risk of neonatal mortality decreased by 5% (aHR=0.95, 95% CI: 0.94-0.97). Household wealth of neonates had a significant effect on neonatal mortality (Likelihood ratio p-value=0.0346). Neonates in the third household wealth quintile had 30% less risk of mortality as compared to those in the poorest household quintile (aHR=0.70, 95% CI: 0.52-0.94). Additonally, the risk of neonatal mortality reduced by 10% for every unit increase in household crowding index (aHR=0.90, 95% CI: 0.85-0.97). However, the individual level variables birth order (Likelihood ratio p-value=0.234), gravidity (Likelihood ratio p-value=0.414) and maternal age at delivery (Likelihood ratio p-value=0.471) were not statistically significant risk factors of neonatal mortality. None of the community level covariates were found to be statistically significant as ethnic heterogeneity (Likelihood ratio p-value=0.850), distance to nearest health facility (p-value=0.761), average travel time to water source (p-value=0.521), poverty (p-value=0.109), sanitation (p-value=0.268) and water safety (p-value=0.647) did not have any statistically significant relationship with the risk of neonatal mortality. Besides, the variance of the community frailty term was found to be $5x10^{-7}$ but was not statistically significant (θ=$5x10^{-7}$, p-value=0.89). This is an implication that there was no unobserved heterogeneity at the community level. Therefore, it can not be concluded that, there were other factors affecting neonatal mortality at the community level that could not be explained by the variables included in the model.

Model IV results

Model IV was the final multilevel cox frailty model constructed to establish the relationship between individual, household and community level variables and the risk of neonatal mortality (Table 7). However, the frailty term was at the household level and it was considered as a better fit compared to Model III which also has a full complement of the variables because the AIC (10203.26) and BIC (10207.50) values of Model III reduced to 9772.61 and 9776.77 respectively in Model IV. Sex of neonates had a significant impact on neonatal mortality as females had 39% less risk of mortality as compared to males (aHR=0.61, 95% CI: 0.51-0.73). Maternal level of education had a statistically significant effect on the risk of neonatal mortality (Likelihood ratio p-value<0.01). Neonates belonging to mothers who had middle, JHS or JSS educational level had 30% excess risk of mortality as compared to neonates whose mothers had no formal education (aHR=1.30, 95% CI: 1.02-1.65). Conversely, neonates whose mothers had secondary or higher level of education had 63% less risk of mortality in comparison with neonates whose mothers had no formal education (aHR=0.37, 95% CI: 0.18-0.75). Neonates whose mothers had no tetanus toxoid vaccine during pregnancy had 32% excess risk of mortality as compared to neonates whose mothers received the vaccine during pregnancy (aHR=1.32, 95% CI: 1.08-1.60). Additionally, neonates of mothers who had previous adverse pregnancy had 38% excess risk of mortality as compared to those whose mothers had no previous adverse pregnancy (aHR=1.38, 95% CI: 1.05-1.83). Place of delivery was also a risk factor for neonatal mortality (Likelihood ratio p-value<0.001).

In comparison with neonates delivered at the hospital, neonates who were delivered at health centre/clinic (aHR=0.40, 95% CI: 0.26-0.60), private maternity home (aHR=0.45, 95% CI: 0.30-0.68) and at home (aHR=0.56, 95% CI: 0.45-0.70) had on the average 60%, 55% and 44% less risk of mortality respectively. Gestational age was found to be significant risk factor in the model. The risk of neonatal mortality reduced by 5% for a week increase in the gestational age of neonates (aHR=0.95, 95% CI: 0.94-0.97). Household wealth of neonates had a significant impact on neonatal mortality (Likelihood ratio p-value=0.0351).

Neonates in the third household wealth quintile had 30% less risk of mortality as compared to those in the poorest household wealth quintile (aHR=0.70, 95% CI: 0.52-0.94). In addition, the risk of neonatal mortality reduced by 9% for every unit increase in household crowding index (aHR=0.91, 95% CI: 0.85-0.97). However, the individual level variables birth order (Likelihood ratio p-value=0.233), gravidity (Likelihood ratio p-value=0.408) and maternal age at delivery (Likelihood ratio p-value=0.472) were not statistically significant in the model. None of the community level covariates were found to be statistically significant. Ethnic heterogeneity (Likelihood ratio p-value=0.847), distance to nearest health facility (p-value=0.759), travel time to water source (p-value=0.498), poverty level in the community (p-value=0.108), sanitation (p-value=0.270) and water safety (p-value=0.650) did not have any statistical significant relationship with the risk of neonatal mortality. Moreover, the variance of the household frailty term was found to be 0.52 but was not statistically significant (ɵ=0.52, p-value=0.48). This gave an indication that there was no unobserved heterogeneity at the household level. Therefore, it can not be concluded that there were other factors affecting neonatal mortality at the household level that could not be explained by the variables included in the model.

CHAPTER SEVEN

SPATIAL ANALYSIS RESULTS OF NEONATAL MORTALITY CLUSTERING IN THE KINTAMPO DISTRICTS

All-Cause Neonatal Mortality Clustering Results in the Kintampo Districts

The Poisson model was used in this analysis that involved 30,132 population at risk with 634 neonatal deaths. Table 8 depicts the villages in each all-cause neonatal mortality cluster while Table 9 presents the results of the spatial scan statistics using the Poisson model. No statistically significant cluster was detected in the model (Table 9). However, four potential clusters were detected for all-cause neonatal mortality with the first cluster (most likely or primary cluster) containing eleven villages, second cluster (a secondary cluster) containing eleven villages and the third (a secondary cluster) and fourth (a secondary cluster) clusters containing only one village (Table 8). The first potential cluster which was in the south-western part of the Kintampo HDSS area had a radius of 8.22 km with 71 all-cause neonatal deaths and a relative risk of 1.51 (p-value=0.333). The second potential cluster can also be located in the south-eastern part of the KHDSS area with a radius of 10.83 km, forty-eight cases and a relative risk of 1.56 (p-value=0.640). The third potential cluster was in the north-western part of the KHDSS area but since it contains only one village (Yaara) and the villages are represented by their centroids, its radius was denoted as 0 km. The number of all-cause neonatal deaths identified in this cluster was five with a relative risk of 3.51 (p-value=0.967). The fourth cluster also contains only one village (Techira No.1) and had five cases with a relative risk of 3.23 (p-value=0.993). This cluster can be located in the north-western part of the KHDSS area. Figure 9 depicts the four potential clusters in the Kintampo Districts

Table 8: Identified potential clusters and their villages in the Kintampo Districts

Cluster number	Village(s) within a cluster
1	Bawa Akura 1, Krabonso, Aworata, Bobrobo, Akruma, Adiembra, Nante, NanteZongo, Tanokrom, Hyireso, Ampoma
2	Abom Basare, Abom Kokonba, Jerusalem, Apesika, Anokyekrom, Akora Nkwanta, Akora, Nyamebekyere, Brechakrom, Attakrom, Asuogya No. 1
3	Yaara
4	Techira No. 1

Source: Adjei (2019)

Table 9: Detected clusters from purely spatial analysis using the Poisson model

Cluster type	No. of villages within a cluster	Radius (km)	Observed cases	Expected cases	Relative risk	p-value
Most likely	11	8.22	71	48.96	1.51	0.333
Secondary	11	10.83	48	31.69	1.56	0.640
Secondary	1	0.00	5	1.43	3.51	0.967
Secondary	1	0.00	5	1.56	3.23	0.993

Source: Adjei (2019)

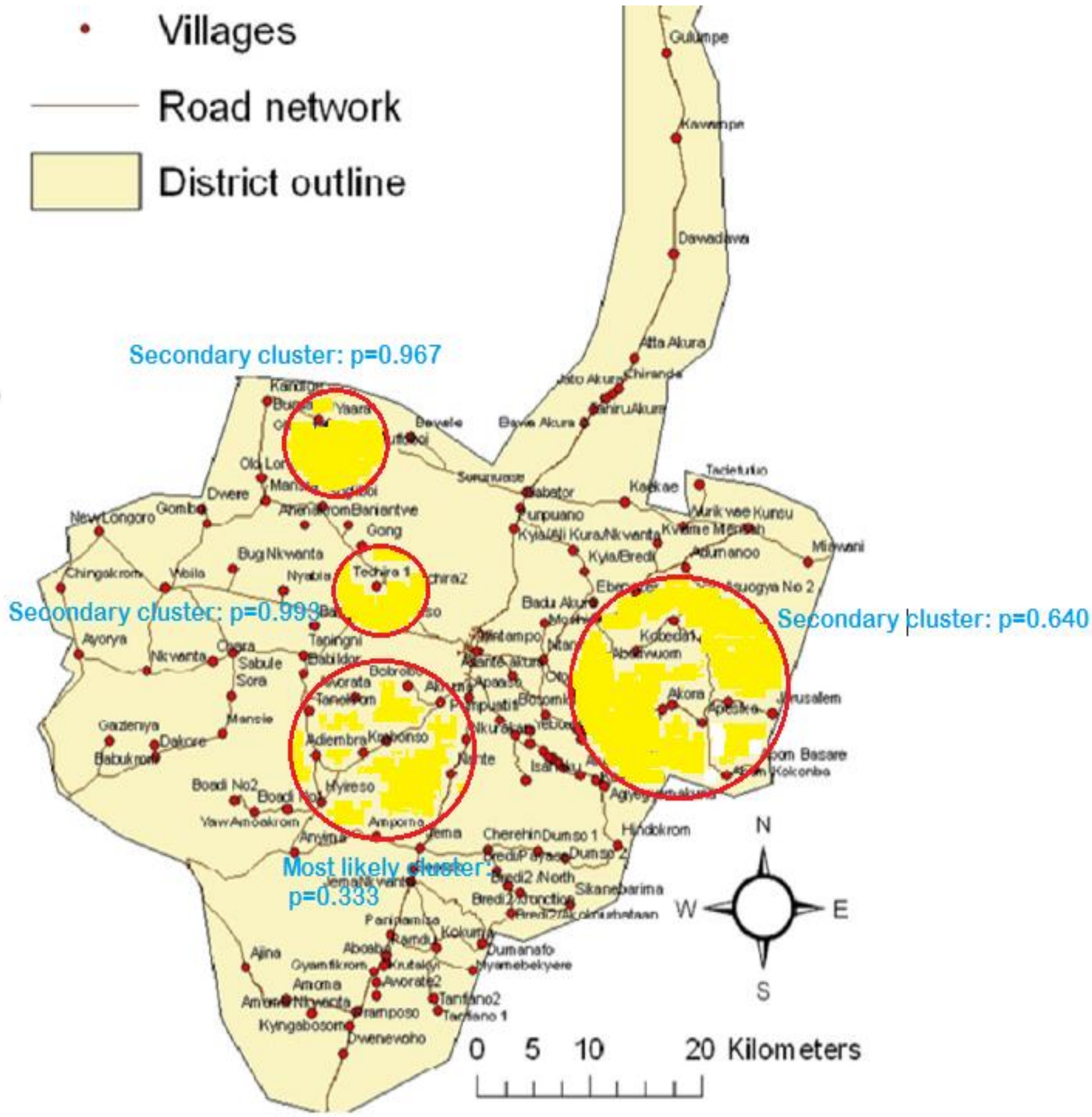


Figure 9: Most likely and secondary clusters for all-cause neonatal mortality in the Kintampo Districts

Source: Adjei (2019)

Cause-Specific Neonatal Mortality Clustering Results in the Kintampo Districts

Table 10 depicts the villages in each detected cluster and Table 11 summarises the cause-specific neonatal mortality results from the Bernoulli model. The analysis involved 474 neonatal deaths attributed to specific causes. This constitutes 74.8% of the 634 neonatal deaths considered in the study. The missing data were due to verbal autopsy interviews which could not be conducted as a result of out-migration and also outstanding verbal autopsy coding yet to be done by physicians.

Two clusters were identified for birth asphyxia related deaths. All the clusters were located in the southern part of the KHDSS area with the first cluster consisting of eighteen villages while the second cluster was made up of three villages. The first cluster (the most likely cluster) which covered a radius of 12.23 km was statistically significant (p-value=0.012) with fifty-six cases and relative risk of 1.98. On the contrary, the second cluster (the secondary cluster) was not statistically significant (p-value=0.608) but had a relative risk of 4.77 and covered a radius of 1.23 km. Figure 10 depicts the primary and secondary clusters for deaths due to birth asphyxia.

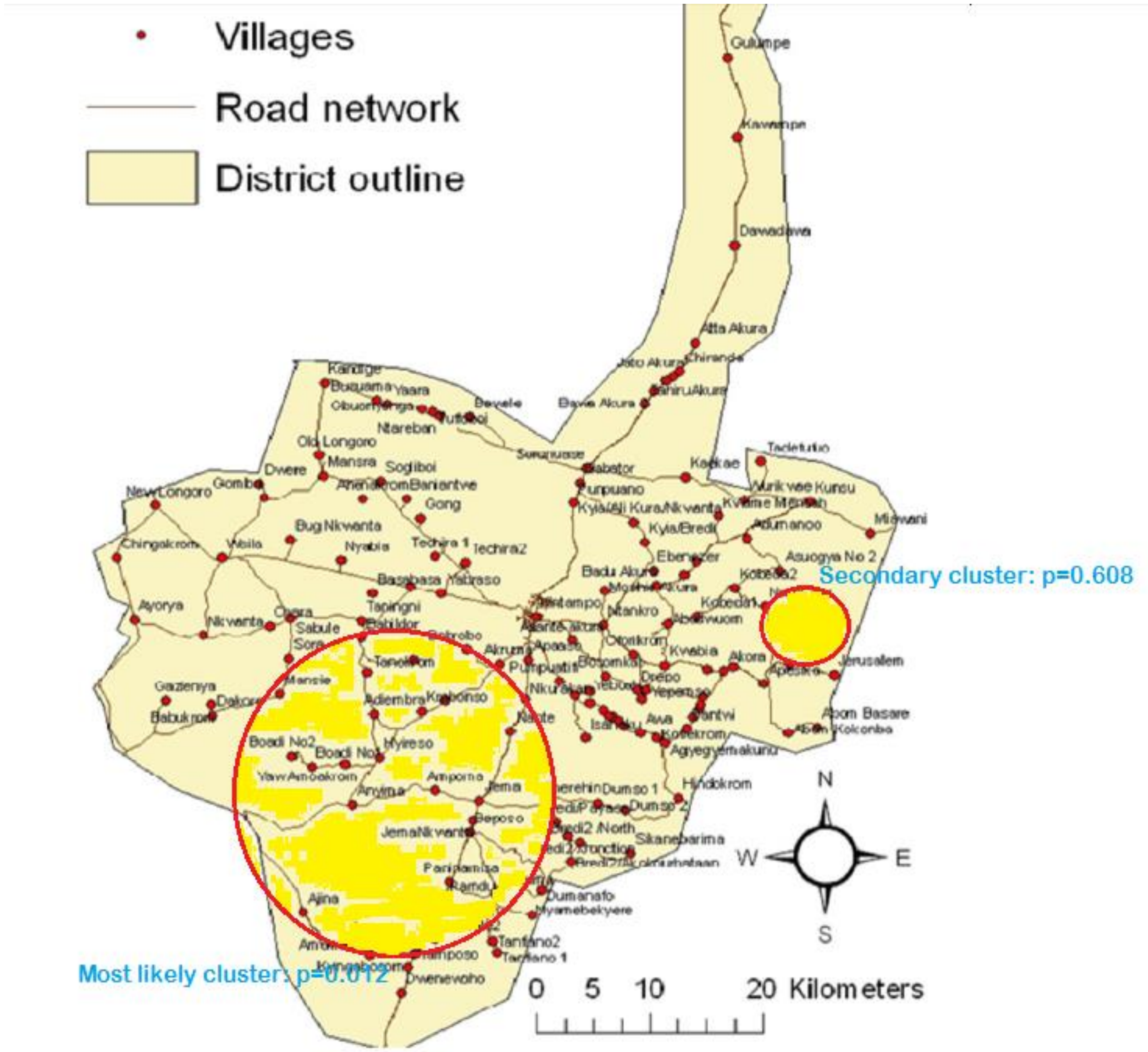


Figure 10: Most likely cluster and secondary cluster for asphyxiated deaths in the Kintampo Districts

Source: Adjei (2019)

There was no cluster detected for the neonatal deaths attributed to congenital cases as there were just two cases in total. Three clusters were detected for infections but none of them was significant. The first cluster (the most likely cluster) which contains three villages and had a radius of 3.46 km was in the southern-western part of the KHDSS. Ten observed infection-related deaths were identified in the cluster which had a relative risk of 2.68 (p-value=0.63). The second potential cluster (a secondary cluster) for infection-related deaths contains forty-one villages covering a radius of 28.09 km in the central part of the KHDSS area. The number of cases in this cluster was 29 and had a relative risk of 1.79 (p-value=0.65). The third cluster (a secondary cluster) for neonatal deaths attributed to infection was also in the north-eastern part of the KHDSS area and also contains only one village (Asuogya No. 1). It had two cases and a relative risk of deaths due to infections to be 8.60 (p-value=0.96). Figure 11 shows the potential clusters for neonatal deaths attributed to infection

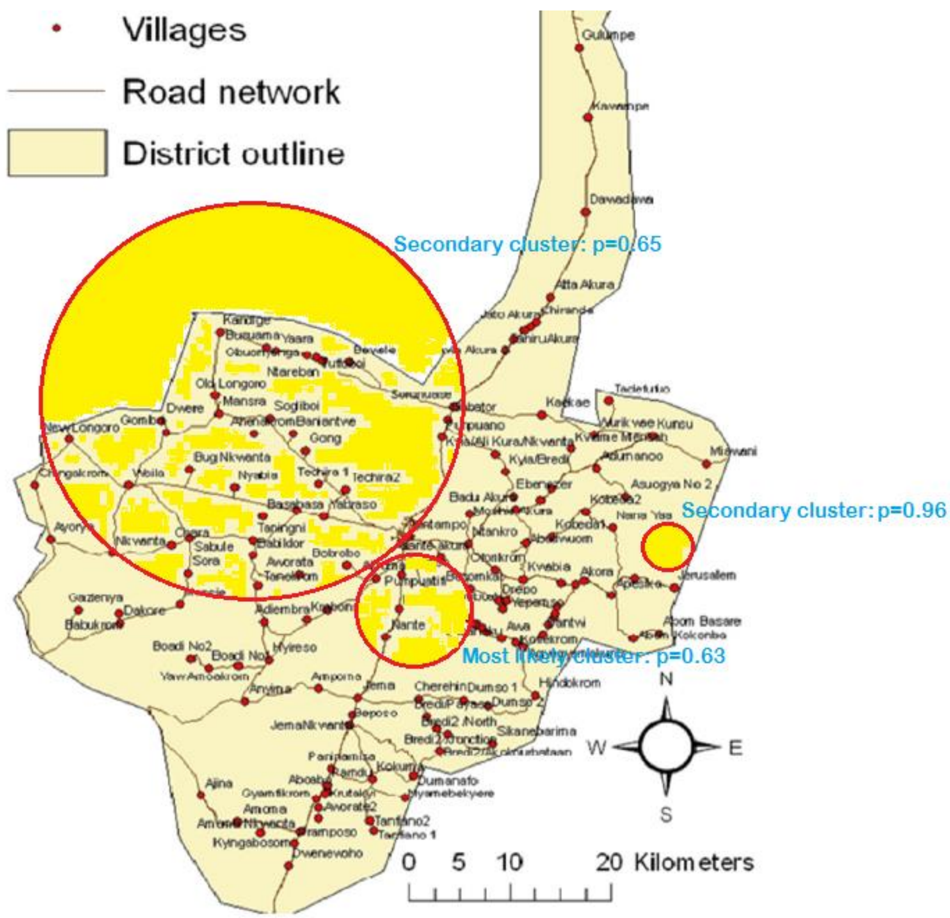


Figure 11: Most likely and secondary clusters for neonatal deaths due to infections in the Kintampo Districts
Source: Adjei (2019)

Three clusters were detected in the southern part of the KHDSS area as a result of deaths due to prematurity. The first cluster was significant (p=0.025) and consists of eight villages covering a radius of 7.03 km. Ten deaths were identified from premature births and the relative risk of cases in the cluster was 5.47. The second cluster had sixteen villages, 6.47 km radius, ten cases and a relative risk of 3.16 (p=0.891). In addition, the third cluster consists of two villages and covering a radius of 4.57 km. Four cases of premature-related deaths were identified in the cluster and a relative risk of 3.00 (p-value=0.993) being the risk of cases. The primary and secondary clusters for premature deaths are depicted in Figure 12

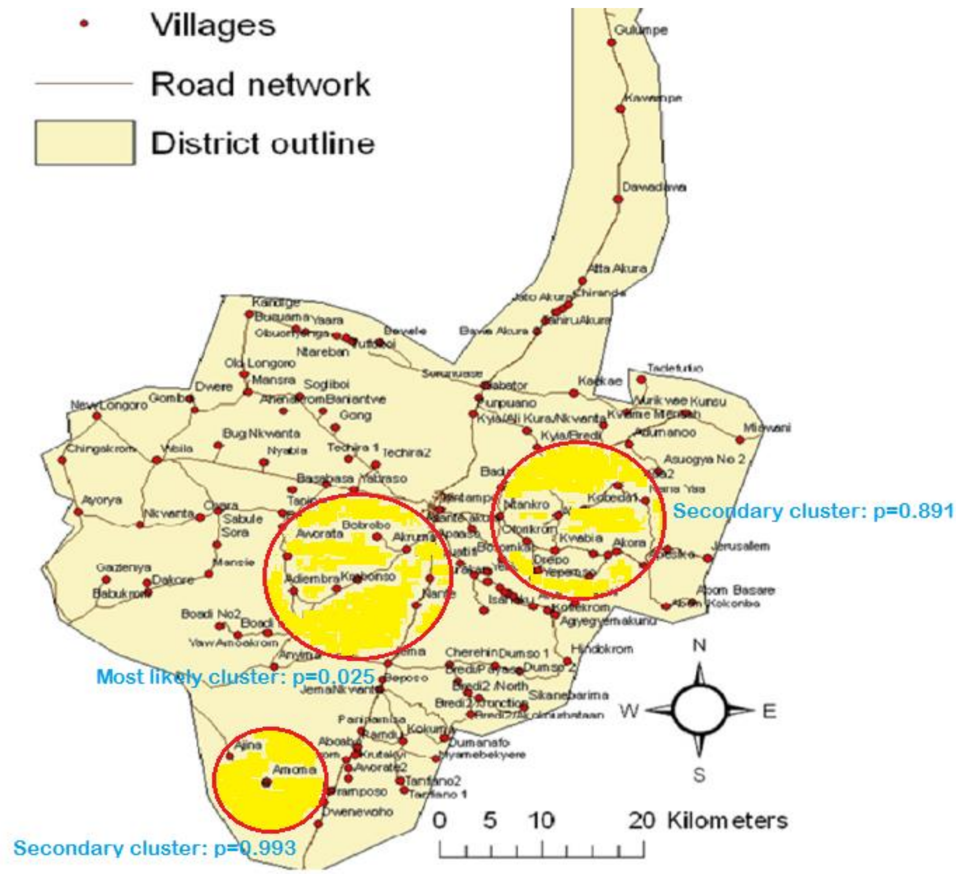


Figure 12: Most likely and secondary clusters for premature deaths in the Kintampo Districts
Source: Adjei (2019)

Regarding neonatal deaths attributed to other causes such as infant haemorrhage, injury etc., three potential clusters were identified; the first cluster (the most likely cluster) being in the southern part, the second cluster (secondary cluster) being in the western part and the third one (a secondary cluster) in the northern part of the KHDSS area. The first cluster had ten villages within a radius of 4.83 km. The number of deaths attributed to other causes in this cluster was seven and the relative risk was 3.20 (p-value=0.810). The second cluster was made up of thirty-four villages and had a 16.35 km radius. The number of cases identified in this cluster was fifteen and had a relative risk of 2.20 (p-value=0.81). There were three villages in the third cluster which had a 3.00 km radius, four cases and a relative risk of 4.35 (p-value=0.85). Three potential clusters attributed to other causes of neonatal deaths are depicted in Figure 13.

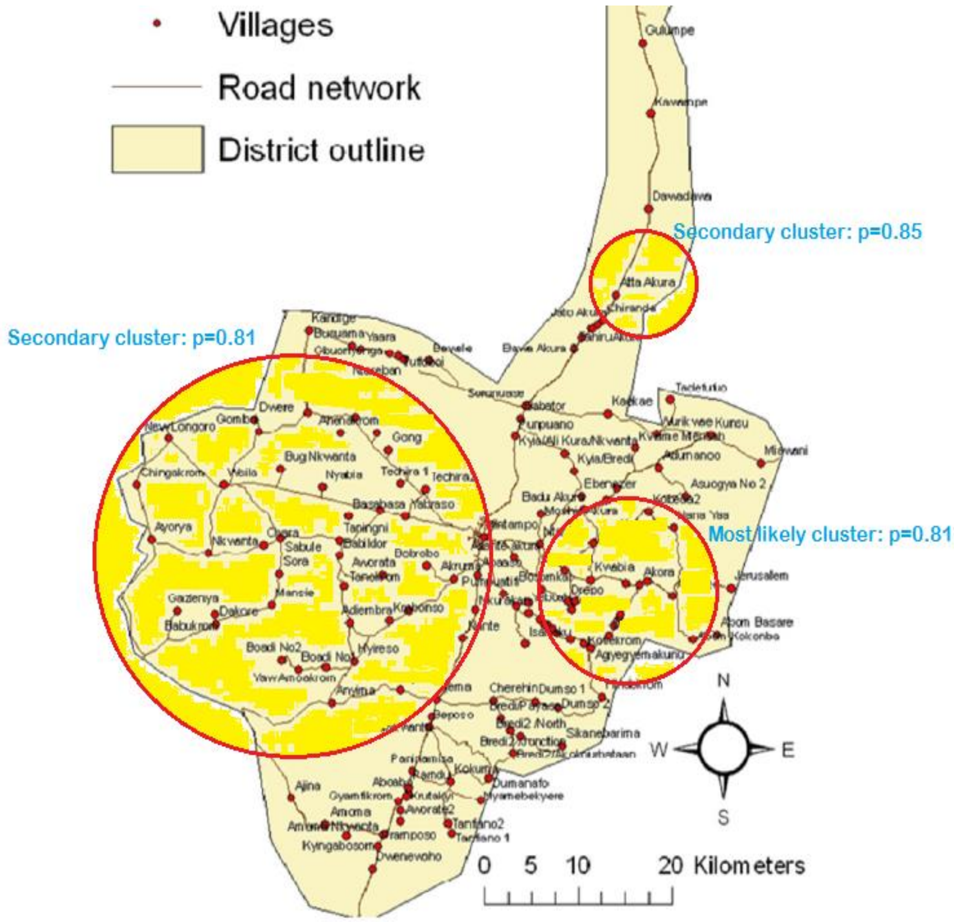


Figure 13: Most likely and secondary clusters for other causes of neonatal deaths in the Kintampo Districts

Source: Adjei (2019)

Two potential clusters were identified for unexplained causes of neonatal deaths; the first cluster (the most likely cluster) was in the north-western part and the other cluster (the secondary cluster) in the southern part of the KHDSS area. The first cluster had a 3.69 km radius with three villages. The number of cases in this cluster was three with a corresponding relative risk of 15.33 (p-value=0.222). The second cluster covered a radius of 0.91 km and consists of two villages. The number of cases in the cluster was three and the relative risk was 7.82 (p-value=0.689). The primary and secondary clusters for unexplained causes are shown in Figure 14.

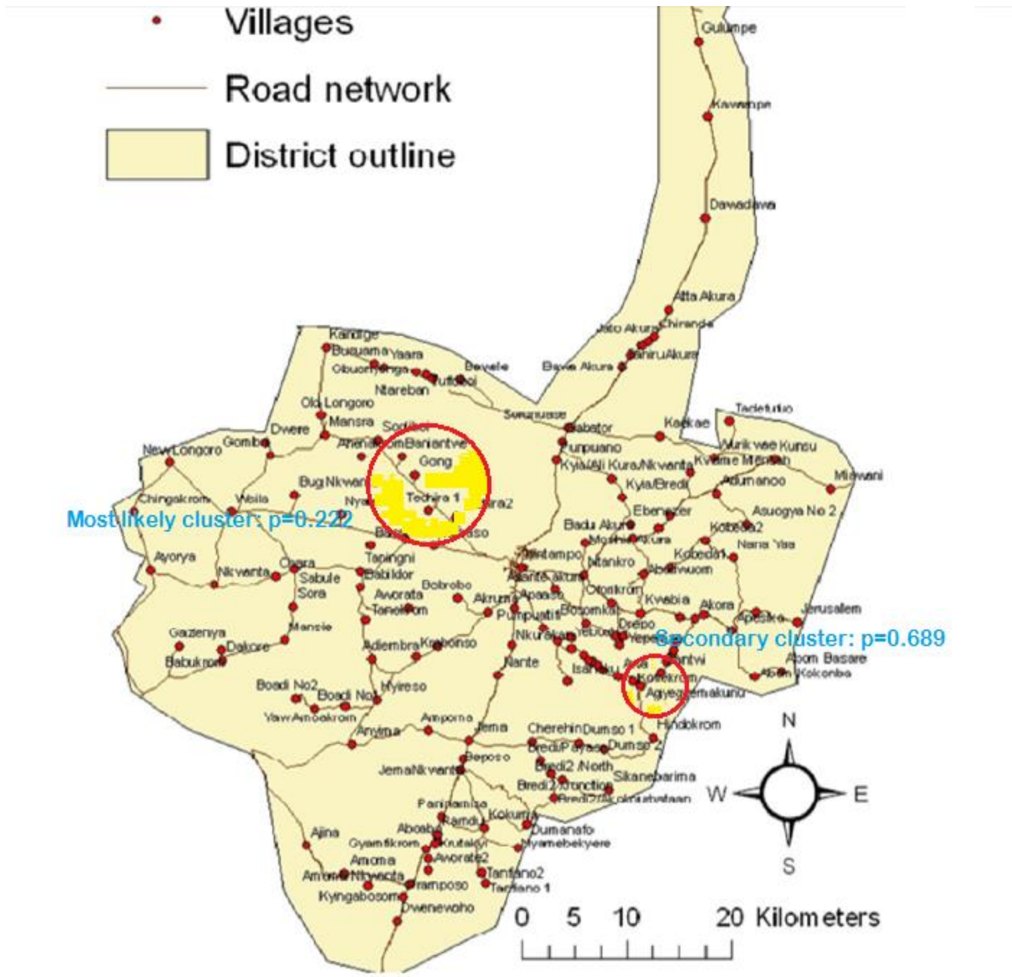


Figure 14: Most likely cluster and secondary cluster for unexplained deaths in the Kintampo Districts

Source: Adjei (2019)

Table 10: Detected clusters and villages for neonatal cause-specific mortality

Cause-specific mortality	Cluster number	Village(s) within a cluster
Asphyxia	1	Anyima, Alhassan Akura No. 2, Yaw Amoakrom, Boadi No1, Hyireso, Boadi No. 2, Ampoma, Adiembra, Krabonso, Beposo, Jema Nkwanta, Ajina, Paninamisa, Jema, Mansie, Pamdu, Tanokrom
	2	Asuogya No 1, Attakrom, Brechakrom
Congenital	-	No cluster detected
Infection	1	Nante Zongo, Nante, Pumpuatifi
	2	Kandige, Busuama, Yaara, Old Longoro, Mansra, Gbuonyonga, Tuffoboi,Sogliboi, Ntareban, Dwere, Ahenakrom, Gomboi, Baniantwe, Bewele, Bug Nkwanta, Gong, Nyabia, Weila, New Longoro, Techira No.1, Basabasa, Asantekwa, Techira2, Sabule, Yabraso, Taningni, Chara, Babiledor Konkonba, Babildor, Soronuase, Babator, Chingakrom, Punpuano, Nkwanta, Sora, Aworata, Tanokrom, Ayorya, Bobrobo, Tahiru Akura
	3	Asuogya No. 1
Prematurity	1	Bawa Akura 1, Krabonso, Aworata, Bobrobo, Akruma, Adiembra, Nante, Nante Zongo
	2	Kwabia, Yepemso, Oforikrom, Drepo, Yeboah, Abudwuom, Fokuokrom, Nyamebekyere, Brechakrom, Attakrom, Akora, Bosomkai, Kobeda1, Asuogya No. 1, Akora Nkwanta, Ntankro
	3	Ajina, Amoma

Table 10 continued

Cause-specific mortality	Cluster number	Village(s) within a cluster
Other	1	Brechakrom, Attakrom, Nyamebekyere, Asuogya No 1, Fokuokrom, Akora, Akora Nkwanta, Agyegyemakunu, Kofiekrom, Kwabia
	2	Sora, Mansie, Chara, Sabule, Babiledor Konkonba, Babildor, Tanokrom, Taningni, Nkwanta, Babukrom, Dakore, Boadi No. 2, Adiembra, Basabasa, Boadi No. 1, Nyabia, Yaw Amoakrom, Aworata, Weila, Bug Nkwanta, Gazienya, Hyireso, Asantekwa, Krabonso, Ayorya, Alhassan Akura No. 2, Bawa Akura 1, Anyima, Yabraso, Gomboi, Bobrobo, Techira No. 1, Ahenakrom, Dwere
	3	Atta Akura, Chiranda
Unexplained	1	Gong, Baniantwe, Techira No. 1
	2	Agyegyemakunu, Kofiekrom

Source: Adjei (2019)

Table 11: Detected clusters for neonatal cause-specific mortality using the Bernoulli model

Cause-specific mortality	Cluster type	No. of villages within a cluster	Radius (km)	Observed cases	Expected cases	Relative risk	p-value
Birth asphyxia	Most likely	18	12.23	56	32.62	1.98	0.012
	Secondary	3	1.23	5	1.07	4.77	0.608
Congenital	No cluster detected	-	-	-	-	-	-
Infection	Most likely	3	3.46	10	3.94	2.68	0.630
	Secondary	41	28.09	29	18.07	1.79	0.650
	Secondary	1	0	2	0.24	8.60	0.960
Prematurity	Most likely	8	7.03	10	2.28	5.47	0.025
	Secondary	16	6.47	6	2.11	3.16	0.891
	Secondary	2	4.57	4	1.43	3.00	0.993
Other	Most likely	10	4.83	7	2.37	3.20	0.810
	Secondary	34	16.35	15	7.85	2.20	0.810
	Secondary	3	3.00	4	0.97	4.35	0.850
Unexplained	Most likely	3	3.69	3	0.21	15.33	0.222
	Secondary	2	0.91	3	0.41	7.82	0.689

Source: Adjei (2019)

CHAPTER EIGHT

DISCUSSION OF RESULTS

Introduction

The study has been guided by four specific objectives which are the risk of neonatal mortality within the first 28 days of life in the study area; the influence of community, household and individual level factors on the risk of neonatal mortality; and spatial clustering of all-cause and cause-specific neonatal mortality in the Kintampo Districts. In addition, the study sought to test four hypotheses. The first hypothesis which states that no statistically significant relationship exists between previous adverse pregnancy and neonatal mortality was rejected based on findings of the study. However, the findings of this study are consistent with the second hypothesis which states that, no statistically significant relationship exists between gravidity and neonatal mortality. The third hypothesis which indicates no statistically significant effect of household crowding on neonatal mortality was rejected based on findings of the study. The fourth hypothesis which states that, spatial clustering for cause-specific neonatal mortality is not statistically significant was also rejected based on the study's findings. Based on the study's objectives which encompass the study's hypotheses, the discussion is in three sections. The first section discussed the risk of neonatal mortality within the first 28 days followed by the second section that discussed the impact of community, household and individual level characteristics on neonatal mortality. The discussion on the effect of individual level factors on neonatal mortality is based on only significant factors. The third and final sections focused on spatial effect on all-cause and cause-specific neonatal mortality. The discussion on neonatal mortality (all-cause and cause-specific) focused on the most likely clusters (clusters with the least p-values). Finally, strengths and limitations of this study have also been discussed.

The Risk of Death within the First 28 Days of Life in the Kintampo Districts

The study revealed the pattern of risk of neonatal mortality within the first 28 days of life in the Kintampo Districts. The risk of neonates dying within the first three days of life was found to be very high and this finding corroborated what is in the literature (Engmann et al., 2012; Lawn, Mongi & Cousens, 2011; WHO Fact Sheet, 2016). However, health intervention coverage within few days postpartum is low in the developing countries (Lawn, Mongi & Cousens, 2011). The high risk of death within the first three days of neonatal life is attributed to high rates of congenital malformation, asphyxia and sepsis (Lawn, Mongi & Cousens, 2011).

The highest risk of neonatal death in this study occurred on day 3 but this is contrary to reports and studies in which the highest risk occurred on day 1 which is the neonate's day of birth (Engmann et al., 2012; UNICEF, 2014; United Nations, 2014; United Nations, 2015; Upadhyay, Rai & Krishnan, 2012). The conflicting findings could be attributed to several factors. This may be due to under-reporting of neonatal deaths during their day of birth which is due to several constraints and factors. Firstly, a registered pregnant woman in the KHDSS may deliver outside the study area so neonatal death during the first day of birth may not be captured. This could also be due to cyclical period within which records are updated. Data are also captured on only individuals who have stayed in the study communities for at least three months (i.e resident population) so pregnant women can migrate to the study area and deliver without the birth being captured. It could also be due to negative cultural practices in which newborns are kept indoors for some days before being out-dooredored (Lawn, Mongi & Cousens, 2011). The Kintampo Health Research Centre has also carried and still been carrying out intervention studies on maternal, child and neonatal health (e.g ObaapaVita, NewHints and EmBRACE studies) and these research activities might have also reduced the risk of neonatal death immensely during the first day.

Risk of neonatal death in the first seven days (first week) of the neonatal period has been established to be higher in comparison with 8-28 days of the neonatal period (Kumar, Singh, Rai, Singh, 2013; UNICEF, 2014; United Nations, 2014). Globally 75% of all neonatal deaths occur in the first week of life. In Ethiopia, Mekonnen and colleagues' (2013) studies revealed that 74% of neonatal deaths occur in the first week of life. In Ghana, Welaga et al.'s study (2013) found that almost 65% of neonatal deaths occurred in the first 7 days. Moreover, our study revealed that 77% of neonatal deaths occurred in the first 7 days of life (not shown). However, the fourth highest risk of neonatal death in the Kintampo Districts is on day 8. Therefore the risk of neonatal mortality in the Kintampo Districts extends up to the 8^{th} day instead of the 7^{th} day of the neonatal life. The proportion of neonatal deaths in the first eight days is 81% (not shown).

The Impact of Individual, Household and Community Level Factors on Neonatal Mortality

Female neonates were found to have lower risk of death than their male counterparts. This finding is in line with the 2014 Ghana Demographic and Health Survey where males have a higher rate of death (GSS, GHS & ICFI, 2015). Findings of several other studies corroborate this finding (Bashir, Ibrahim, Bashier, Adam, 2013; Mekonnen, Tensou; Telake, Degefie, Bekele, 2013; Selemani et al., 2014; Kumar, Singh, Rai, Singh, 2013; Titaley, Dibley, Agho, Roberts, Hall, 2008). Welaga et al .(2013) and Kayode et al. (2014) have shown that risk of death among male neonates is higher in Ghana but it is not statistically significant. Both studies included both single and multiple births in their analysis and multiple births were found to have a higher risk of neonatal death compared to single births. Perhaps the imbalance effect of multiple births across both sexes attenuated the relationship between risk of neonatal death and sex of neonates. The biological make-up of male neonates naturally predisposes them to risk of mortality. This is as a result of weaker immune system among males attributed to congenital malformation of the urogenital system (Singh, Kumar & Kumar, 2013; Titaley, Dibley, Agho, Roberts, Hall, 2008; Tymicki, 2009).

The weaker immune system among male neonates is the more plausible reason for this study finding, unlike some studies in Asia where there is excess mortality among females as a result of discrimination in care between male and female neonates (Muhuri & Preston, 1991; Pebley & Amin, 1991; Shell-Duncan & Obiero, 2000). Studies in Asia have shown that males are used as economic security since they have economic opportunities more than the females and can therefore be more likely to help in taking care of other siblings at a later stage in the father's life or when the father is too old to work (Muhuri & Preston, 1991; Pebley & Amin, 1991; Shell-Duncan & Obiero, 2000). In addition, the dowry price of females in Asia is expensive and consequently make it less affordable (Muhuri & Preston, 1991). Due to this reason coupled with limited economic opportunities of females, they (females) are seen as economic burden and males are therefore given better care and attention (Muhuri & Preston, 1991). However, this differential treatment occurs beyond the neonatal period (Muhuri & Preston, 1991; Pebley & Amin, 1991; Shell-Duncan & Obiero, 2000) and hence the possible reason attributed to higher risk of death among male neonates in this study is more likely to be biological differences.

Maternal level of education also had an impact on neonatal mortality in this study. Neonates whose mothers have middle, JSS or JHS educational level have a higher risk of death than neonates whose mothers do not have formal education.

On the contrary, neonates whose mothers have secondary or higher level of education have lower risk of death than those whose mothers do not have formal education. Singh (2013) and Mekonnen et al.'s (2013) studies in India and Ethiopia respectively have been able to establish that higher maternal educational level has a lower risk of neonatal mortality. According to literature, higher maternal level of education improves neonatal health outcomes through several channels which includes knowledge and competence of child healthcare; better hygienic practices; more exposure to information and being able to act on this information promptly; able to understand health information better; affordability of healthcare; accessibility of antenatal and prenatal care and the tendency to deliver at the health facility (Buor, 2003; Kravdal, 2004; Rahman, 2009). However, neonates whose mothers had middle, JSS or JHS education have a higher risk of death. Further analysis of the data revealed that, the proportion of neonates whose mothers were teenagers at childbirth and had middle/JSS/JHS educational level, was 18.9% as compared to 6.9% of neonates whose mothers were teenagers at childbirth and without formal education. This indicates that, proportion of neonates whose mothers are teenagers and have educational level to be middle/JSS/JHS, is more than twice the proportion of neonates whose mothers are teenagers and without formal education. The higher proportion of teenage mothers among women with middle/JSS/JHS educational level could be the possible explanation for higher risk of neonatal mortality among this category of women in comparison with women without formal education. The mechanism underlying this phenomenon is that, teenagers are not psychologically and physiologically matured to deliver a baby and these reasons pose a high risk of neonatal mortality among pregnant women who are teenagers (Gyimah, 2002b; Tymicki, 2009).

Neonates whose mothers failed to receive tetanus toxoid (TT) injection during pregnancy periods have been also revealed by this study to have higher risk of mortality. This finding is in line with the findings of other studies (Blencowe, lawn, Vandelaer; Roper, Cousens, 2010; Mekonnen, Tensou; Telake, Degefie, Bekele, 2013; Singh, Pallikadavath, Ogollah, Stones, 2012; Singh, Kumar & Kumar, 2013). In 2015 alone, tetanus caused 19,937 neonatal deaths worldwide (Kyu et al., 2015). In spite of this number that died from tetanus, coverage of tetanus toxoid vaccination in sub-Saharan Africa is the lowest globally (UNICEF, 2015). Coverage is required to increase for the subsequent eradication of this canker. According to 2014 Ghana Health and Demographic Survey report, 78% of births are protected against tetanus but if coverage of tetanus toxoid vaccination is increased and there is huge reduction of pregnant women delivering in an insalubrious environment such as the home, tetanus can be eliminated to avert many neonatal deaths in Ghana.

Neonates whose mothers had previous adverse pregnancies as a result of foetal deaths (miscarriages, stillbirths and ectopic) have an increased likelihood of mortality in comparison with neonates of mothers who did not experience any adverse pregnancies. This finding supported the findings of studies that were carried out in Sudan (Ibrahim, Babikert, Amin, Omer, Rushwan, 1994) and Uganda (Kujala et al., 2017) in which mothers with previous adverse pregnancies had 2 and 4 fold increased risk of neonatal mortality. This suggests that previous foetal deaths are linked to the biological deficiency in the reproductive capacity of mothers (Tymicki, 2009; Vandresse, 2006) and this is critical for intervention strategies aimed at reducing neonatal mortality in districts which have similar characteristics as Kintampo Districts.

Paradoxiacally, neonates belonging to women delivering at home, private maternity home or health centre/clinic have a lower risk of mortality in comparison with neonates whose mothers delivered at the hospital. Kintampo is predominantly rural (65% of the population is rural) and the study's data showed that, most of the mothers (47.4%) deliver at home in comparison to 34.3% who deliver at the hospital. In total, 65.7% of the mothers deliver at health centres/clinics, private maternity homes, TBAs' houses, home and other places. Therefore, one of the possible reasons attributed to this finding is the fact that the Kintampo Districts' hospitals serve as referral hospitals for health centres/clinics, private maternity homes, TBAs' houses, etc in the adjoining communities of their catchment area and because of that, severe cases of pregnancies are referred there (Ajaari, Masanja, Weiner, Abokyi, Owusu-Agyei, 2012). The other possible reason may be newborns who are delivered in hospitals and ended up dying at home in the early neonatal period as a result of infections that are high during the early neonatal period (Lawn, Mongi & Cousens, 2011). Further analysis of the data revealed that, mothers of neonates who were delivered at the hospital had more previous adverse pregnancy outcomes (13.5%) than mothers (10.2%) of neonates who were delivered at home. This could be a possible reason for a higher risk of neonatal mortality among neonates delivered at the hospital than at home.

This study investigated the effect of increasing gestational age on the risk of neonatal mortality. Risk of neonatal mortality decreases for a week increase in gestation age and this has been amplified in the literature (Marchant et al., 2012; WHO, 2012; Sharma, 1997). Findings of several studies in Africa and Asia (Debelew, Afework, Yalew, 2014; Marchant et al., 2012; Nisar & Dibley, 2014; Shah et al, 2014; Sutan & Berkat, 2014, Welaga et al) are also in line with this finding of the study but they expressed gestational age in two categories namely preterm (less than 37 weeks of gestation) and term births (37 or more weeks of gestation).

Household wealth which serves as a proxy index for socio-economic status has been shown by this study to have an impact on neonatal mortality. It has been far advanced in the literature that household wealth exerts impact on neonatal mortality through a set of proximate determinants. Hence, the poorest household is more likely to lack proper education, quality healthcare, good nutrition and proper sanitation (Fotso & Kuate-Defo, 2005; Sastry, 1996). In this study neonates belonging to households in the third quintile have less risk of mortality in comparison with neonates in the poorest households. One of the possible reasons may be education since the highest proportion of neonates (23.1%) [not shown] whose mothers had educational level to be secondary or above are those in the third quintile. The other possible reasons may be that, neonates who are in the third quintile have access to good quality healthcare because of the ability of their parents to afford the cost. The lack of good housing quality and environment may also be a possible reason that predisposes neonates in the poorest households to death.

Ironically, an increase in crowding index is found to reduce the risk of neonatal mortality. Available evidence rather shows that crowding increases the risk of death since that enhances the spread of pathogens directly from one household member to the other (Aaby, 1987; Vajpayee & Govilla, 1987; Woldemicael, 2000). However, Fikree (1993) has posited that mortality through the spread of infectious diseases is more likely to occur in the post-neonatal period than the neonatal and the perinatal periods. He further argued that perinatal and neonatal mortality is related more to the maternal environment during pregnancy, labour and delivery (Fikree, 1993). Hence, any association between crowding and the risk of neonatal mortality may operate through psychosocial stress of the mother (which has been established by literature to have an effect on premature labour which is also associated with high risk of perinatal and neonatal mortality) resulting from crowding (Fikree, 1993). Another possible reason is the limitation of the crowding index in which the area of the sleeping rooms for the household members have not been standardised. For example, a household may have many people for a sleeping room but the sleeping room might be quite larger than that of another household which has few people.

Contrary to the findings of other studies, none of the community level factors was found to have a statistically significant effect on neonatal deaths (Kayode et al., 2014; Mekonnen, Tensou; Telake, Degefie, Bekele, 2013; Titaley, Dibley, Agho, Roberts, Hall, 2008). The possible reason may be the disparity in the operational definition of communities. Unlike the communities of the other studies which are census tracts, survey clusters etc. (Boco, 2010; Kayode et al., 2014; Adedini et al., 2015), the communities in this study are health administrative sub-districts in which members in these communities are likely to be educated through activities of CHPS compounds and health centres. Moreover, this study did not have evidence to show that factors at the household (e.g genetic, mothers' breastfeeding practices etc.) and community (e.g poor road network, electricity etc.) levels that were not taken into account had statistically significant effect on neonatal mortality. However, there was unobserved heterogeneity at the household level for a study conducted in Uganda but this study focused on under-five deaths (Nasejje, Mwambi & Achia, 2015).

All-Cause and Cause-Specific Neonatal Mortality Clustering in the Kintampo Districts

This study also looked at the neonatal mortality clustering in the study area. The most likely cluster for all-cause neonatal mortality was in the South-Western part of the Kintampo Districts and contains eleven villages. Of the eleven villages, Nante (32.4%), Ampoma (18.3%), Krabonso (15.5%), Hyireso (15.5%) and Nante

Zongo (11.3%) are the villages that contributed most to the 71 deaths that occurred in the cluster. Apart from Nante, Ampoma and Nante Zongo which are close to the district hospital in Jema and are linked to Jema by the main highway, Hyireso and Krabonso are far from Jema and their road linking the main highway to Jema is bad. Means of transport are also not readily available. Perhaps the high proportion of all-cause neonatal deaths in these two villages are due to delay in transporting neonates to the district hospital during emergency situations. The common factor that may be attributed to a higher all-cause neonatal mortality in the five villages is a lower proportion of mothers with secondary or higher level of education. Further analysis of the data revealed that the proportion of mothers with secondary or higher educational level in the five villages constitute only 2.4% of all mothers with that level of education.

With regards to cause-specific neonatal mortality, the most likely cluster with eighteen villages had a statistically significant effect on asphyxiated deaths. Nine of the villages namely Jema (19.6%), Anyima (16.1%), Pamdu (12.5%), Mansie (8.9%), Ajina (7.1%), Paninamisa (7.1%), Ampoma (7.1%), Krabonso (7.1%) and Hyireso (5.4%) contributed a significant proportion of the asphyxia-related deaths. Ampoma, Krabonso and Hyireso that contributed significantly to all-cause mortality are also included in this cluster. Apart from Jema, Ampoma, Paninamisa and Pamdu which do not have bad road and transportation problems, the others have these problems. Since asphyxia-related deaths usually occur on the day of birth, the possible reason for the villages with unmotorable roads and the lack of transportation might have been delays in reaching the hospital when there were labour complications. Further analysis of the study data supports the aforementioned reason since nearly half (48%) of the asphyxiated deaths in these villages occurred in the hospital and this may be due to delay in reaching the hospital. Asphyxiated deaths that occurred at Jema, Ampoma, Paninamisa and Pamdu needs further research to find the possible explanation for that.

The most likely cluster for deaths attributed to infections has three villages with Nante (50%) and Nante Zongo (40%) contributing most to the ten cases that occurred in the cluster. The possible cause of the infection-related deaths in these villages is mainly due to maternal education since almost seventy-eight percent (77.8%) of these deaths are from neonates belonging to mothers who do not have formal education.

There was significant clustering for premature neonatal deaths. Villages that contributed high proportions of these deaths are Nante (60%) and Krabonso (30%). Maternal education may be the commonest reason for these deaths occurring in both villages. However, other reasons such as delay in reaching the referral hospital in Jema as a result of bad road and the lack of readily available transportation may be the underlying causes of deaths at Krabonso.

The most likely cluster for other-related deaths contains villages that are in the outskirts of southern part of Kintampo Districts. Therefore, deaths of this nature may be due to poor socio-economic status, unmotorable roads, poor housing conditions, lack of transportation and low maternal level of education. For instance morbidity like malaria needs prompt treatment and where there is lack of transportation, reaching the nearest health facility might delay unnecessarily and may subsequently result in the death of the newborn.

The most likely cluster for unexplained deaths is in the northern part of the Kintampo Districts. Though not statistically significant, it has the potential for significant mortality clustering. It contains three villages namely Gong, Baniatwe and Techira No. 1 which are in the outskirts of the northern part of the Kintampo Districts. The northern part has few health facilities, health personnel, modern amenities such as electricity, good sanitation facilities etc. The nearest hospital of these villages in the north is the Kintampo North Municipal Hospital which is far from these villages and moreover transportation is not readily available in these villages during emergency situations. Socio-economic status in these villages within the cluster is also poor and road networks are also bad. All the enumerated factors may lead to clustering for unexplained neonatal deaths.

Strengths and Limitations of the Study

This study has the strength of using longitudinal data which has the characteristic of establishing temporality (risk factors preceding the outcome). Unlike survey data, children from the same household can be continuously followed up to collect data on a common set of risk factors.

This study used the multilevel cox proportional hazards model which has a number of advantages. Firstly, the multilevel cox proportional hazard has the ability to assess both the fixed and random effects in a single model (Kayode et al., 2014; Nasejji, Mwambi & Achia, 2015). In addition, it disentangles the individual, household and community level effect on neonatal mortality, while controlling for the hierarchical levels in the data at the same time (Kayode et al., 2014; Nasejji, Mwambi & Achia, 2015; Duncan, 1998). In other words, it takes the hierarchical nature of the data into account and therefore any differential effect that might be due to any of the hierarchical levels could be discerned. Unlike this model, many other models consider observations to be at the same level and therefore makes it unlikely to attribute the effect to a particular level and thus leading to underestimation of the standard errors to give spurious results (Duncan, 1998). Due to frailty term, this method also overcomes the bias due to unobserved heterogeneity at the household and community level (Boco, 2010). However, this method has a limitation of hazard ratios decaying over time in favour of frailty effect. The degree of decay depends on the frailty variance θ, and when θ is close to zero the hazard ratios regain their usual interpretation (Gutierrez, 2002). Since θ was close to zero in this study, the degree of decay was minimal.

Furthermore, the study has a limitation of some missing values. However, these missing values are minimal. Apart from the variable crowding which has 83.5% of the total records (30,132) intact, the rest of the variables with missing values have more than 99% of the total records intact.

Using the Kulldorf method of spatial analysis also has the strength of controlling for covariates in multivariate analyses. Moreover, it has the power of rejecting the null hypothesis when it is indeed false. However, it has a limitation of including low-risk areas surrounded by high-risk areas in a cluster, since it uses a circular window to scan for high-risk clusters (Kulldorff, 2015). The spatial analysis results for this study identified all the low-risk villages which were surrounded by high-risk villages. Therefore, any future intervention rolled out would be able to identify all the high-risk villages.

The study has some other limitations. Neonatal deaths are likely to be under-enumerated due to the difficulty in the collection of information related to neonatal deaths in developing countries (Eisele et al., 2003; Sankoh, Ye, Sauerborn, Muller, Bercher, 2001). However, this will be reduced in this study since the study has Community Key Informants (KII) who report any events of births and deaths in-between the scheduled household visits. Out-migration of residents for a long period might also lead to some loss of information. However, this is minimised by collecting their household data when they return to the KHDSS area. Moreover, this number is usually not too huge to affect data quality. Finally, findings of this study can not be generalised to the whole country but rather to areas in Ghana which have similar characteristics as Kintampo Districts.

Ethical Consideration

The study was carried out by analysing secondary dataset. Study participants confidentiality was ensured since unique ID codes were used to identify them. In addition, verbal consent was sought for interviews conducted and participants were at liberty to refuse consent at anytime without any punishment or penalty. Field supervisors who conducted VPM interviews had been trained to handle psychological emotions. Besides, this study used an already existing data from the KHDSS database. The KHDSS is one of the HDSS sites in Ghana which already has ethical clearance from the Research Development and Division (of the Ghana Health Service) Ethical Review Board for its core HDSS activities.

CHAPTER NINE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter presents summary, conclusion and recommendation of this work. The summary gives an overview and key findings of the study. Additionally, the conclusion is based on the key findings of the study. Moreover, contribution to knowledge made by this study is also presented. Finally, recommendations based on policy, practice and suggestions for future research have been given.

Summary

This study investigated the effect of individual, household, community and spatial factors on the risk of neonatal mortality in the Kintampo Districts using 10 year longitudinal data of the KHDSS. Each administrative sub-district was considered as a community and the composition of each sub-district were the individual and household factors. The study examined the risk of neonatal mortality on each day of the first 28 days of neonatal life in the Kintampo Districts using the incident rate. The impact of individual, household and community level factors on risk of neonatal mortality was also analysed by using multi-level cox frailty models. Besides, all-cause and cause-specific neonatal mortality clustering were examined using the Kulldorff Method in a purely spatial scan statistics.

Pregnancies of resident women in the study area within the study period (January 2005- December 2014) were registered and followed-up till the women delivered. The socio-demographic characteristics of these women were collected periodically and only newborn singletons were considered in this study. Verbal autopsies of all neonatal deaths were also conducted to ascertain the cause of death.

Moreover, all compounds of households, villages and sub-districts were geocoded and these were employed in the spatial mortality clustering analysis.

One of the key findings of this study was that risk of neonatal mortality was very high in the first three days of neonatal life within the Districts. Additionally, the risk of neonatal mortality was much higher on days 1-8 as compared to days 9-28. Moreover, neonates born to mothers who experienced previous adverse pregnancy (stillbirths, miscarriage or ectopic) as compared to neonates born to mothers who did not experience any previous adverse pregnancy and neonates whose mothers' educational level was middle, JHS or JSS as compared to those whose mothers did not have formal education had higher risk of death. Besides, neonates whose mothers did not receive tetanus toxoid injection during pregnancy as compared to those whose mothers received tetanus toxoid injection had higher risk of mortality.

However, female neonates and neonates whose mothers' educational level was secondary or higher as compared to neonates born to mothers without formal education had lower risk of mortality. Additionally, neonates with longer gestation period and neonates in households with crowded sleeping rooms had lower risk of mortality. Besides, neonates who belonged to the third household wealth quintile in comparison with those in the poorest households had lower risk of mortality. Neonates who were delivered at home, private maternity home or health centre/clinic as compared to neonates delivered at the hospital had a lower risk of mortality. The study also found significant clustering for asphyxia- and premature-related deaths.

Conclusion

This work has been able to address the objectives and hypothesis set out. It has also been able to contribute to the understanding of neonatal mortality risk, especially in the Kintampo Districts.

The findings of the study indicated that risk of neonatal mortality in the Kintampo Districts is higher in the early neonatal period. Contrary to findings of higher risk of early neonatal deaths in the first seven days, this finding suggests higher risk in the first eight days.

The study showed inequality in the risk of neonatal mortality to the disadvantage of male neonates. This finding suggests more of underlying biological reason than any other reason. Also, the study revealed that previous adverse pregnancy of mothers could compromise their biological reproductive mechanism and consequently lead to a higher risk of neonatal mortality.

Higher risk of mortality among neonates whose mothers do not receive tetanus toxoid injection during pregnancy suggests that, improving antenatal care utilisation can contribute to saving lives of neonates. Delivering outside hospital associated with lower risk of neonatal mortality, suggests mothers visit the hospital too late when their situation during childbirth has become critical. In addition, longer gestation period of neonates appears to be important for the reduction in risk of neonatal mortality. Mothers' educational level being secondary or higher tends to improve the capacity of mothers in childcare since neonates of those mothers have lower risk of death. Paradoxically, this study's findings suggest higher risk of mortality for neonates whose mothers' educational level is middle, JHS or JSS.

Regarding household factors, the study suggests that inequality in socio-economic status of households results in differential risk of mortality as neonates belonging to higher socio-economic households appears to have lower risk of death. Paradoxically, the study suggests neonates belonging to households with crowded sleeping rooms tends to have lower risk of mortality. These findings at the household level suggest that factors affecting neonatal mortality in the Kintampo Districts go beyond individual level factors.

The study suggests higher risk of asphyxia-related deaths in some cluster of villages in the Kintampo Districts. Also, premature deaths appears to be higher than average in some cluster of villages in the Kintampo Districts.

Contribution to Knowledge

Several past studies (Edmond, Kirkwood, Amenga-Etego, Owusu-Agyei, Hurt, 2007; Kayode et al., 2014; Kirkwood et al., 2013; Manortey et al., 2011; Singh et al., 2013) on risk of neonatal mortality in Ghana did not consider the health administrative sub-district as a community (or cluster). This study has been able to fill that gap in the literature. Moreso past studies (Edmond, Kirkwood, Amenga-Etego, Owusu-Agyei, Hurt, 2007; Kayode et al., 2014; Kirkwood et al., 2013; Manortey et al., 2011; Singh et al., 2013) that considered risk factors of neonatal mortality in Ghana did not consider the effect of previous adverse pregnancy on risk of neonatal mortality. This study has been able to provide evidence on previous adverse pregnancy and its effect on risk of neonatal death. The literature has also been expanded on the effect of crowding on the risk of neonatal mortality which previous studies on neonatal mortality did not consider. Real time of exposure is important in the calculation of risk. This study therefore added to the literature by using person-days to calculate risk of neonatal mortality in the first 28 days as compared to already existing studies (Edmond, Kirkwood, Amenga-Etego, Owusu-Agyei, Hurt, 2007; Engmann et al., 2012; Welaga et al., 2013) that used percentages. This study was able to demonstrate that irrespective of two neonates born as preterm babies or term babies, the one with a longer gestation period has a larger chance of survival. This finding has expanded the literature in this area because previous studies in Ghana categorised neonates gestation periods into term and preterm status (Edmond, Kirkwood, Amenga-Etego, Owusu-Agyei, Hurt, 2007; Welaga et al., 2013). Previous studies (Adjuik, Kanyomse, Wak, Hodgson, 2010; Arku et al., 2016; Nettey, Zandoh, Sulemana, Adda, Owusu-Agyei, 2010) on spatial effect on child mortality in Ghana rarely considered all-cause and cause-specific neonatal mortality in Ghana. However, this study filled that gap by providing empirical evidence on all-cause and cause-specific neonatal mortality clustering, Finally, longitudinal data have a strength of establishing temporality and therefore reliable for the provision of intervention. However, the previous study (Kayode et al., 2014) used purely cross-sectional data for its multilevel analysis. This study has therefore expanded the literature by using longitudinal data in its multilevel analysis.

Recommendations

The study findings suggest that, risk of neonatal mortality within the first three days in the Kintampo Districts is very high. To reduce this early risk of neonatal mortality, it is recommended to intensify the already existing activities of

District and sub-District Health Management Teams, whereby mothers who deliver are visited in the community for early postnatal care.

The activities of early postnatal care in the Kintampo Districts could be intensified in the following ways. Firstly, the number of community healthcare nurses (CHNs) in the 12 sub-districts could be increased by the district health directorate in consultation with Ghana Health Service to cover a wide area in the sub-districts thereby visiting a lot of newborns to undertake early postnatal care. Furthermore, with the support of Ghana Health Service and other stake holders, activities of community-based volunteers (CBVs) could also be strengthened by giving them incentives to facilitate reporting of fresh births to health management teams in the Districts and sub-districts to enhance early postnatal care. In addition, the number of CBVs can also be increased to ultimately increase the number of births reported to DHMTs and CHNs for prompt action on early postnatal care. Traditional Birth Attendants (TBA's) can also be educated by districts and sub-districts health management teams to report births to CHNs in the sub-districts for early postnatal visits. Some negative cultural practices such as keeping newborns indoors for some number of days, serve as barriers for early postnatal visits. These negative cultural barriers could be reduced to enhance early postnatal visits by forming committees of opinion leaders such as chiefs, pastors, TBAs, traditional healers etc. in the villages to educate women and their husbands to report fresh births. All the afore-mentioned measures aimed at increasing early postnatal visits have cost implications so governments can partner non-governmental organisations

(NGOs) and developing partners (DPs) to achieve these goals through the Ghana Health Service.

Programmes and activities of health workers in the districts and sub-districts aimed at reducing neonatal mortality in the Kintampo Districts should encourage mothers to visit health facilities especially during the first 8 days after delivery, since risk of early neonatal deaths in the districts is within the first eight days. This could be done through radio messages, committees of opinion leaders and also delivering messages to pregnant women in their local dialect personally through mobile phones when their day of delivery is close. This can also be done when pregnant women attend ANC and during early post-partum periods. CHNs could also follow-up on deliveries.

The study findings suggest that neonates whose mothers do not receive tetanus toxoid (TT) vaccine during pregnancy have higher risk of mortality. Pregnant women should therefore be encouraged by health workers in the districts and sub-districts to attend ANC and complete immunisation schedule during pregnancy. This finding also suggests that minimising bottlenecks in the health system that impede high coverage of this vaccination will eventually reduce the risk of neonatal mortality in the Kintampo Districts. Minimising these bottlenecks could be done by intensifying education in the sub-districts through radio jingles, counselling during ANC services, documentary films in villages of the sub-districts, committees of opinion leaders and outreach services of CHPS compounds and health centres. Another way of removing these bottlenecks is to make available tetanus toxoid vaccine in the sub-districts with the required cold chain system in place.

Available evidence from the study also suggests that women with secondary school or higher education have the tendency to reduce their newborns' risk of mortality. This has implication for the new government policy for free senior high school education which commenced in 2018. The commitment of government to continue this policy which is associated with high cost, can increase the number of women with secondary education in the Kintampo Districts to ultimately minimise risk of neonatal mortality in the districts. The district assemblies in the Kintampo Districts can take advantage of this policy and facilitate the girl-child education, right from the basic level to the secondary level.

Neonates who have a high risk of death as a result of previous adverse pregnancy outcome has implication for Ghana National Newborn Health Strategy and Action Plan (GNNHSAP) 2014-2018, which is a roadmap developed by Ghana Health Service (GHS) and Ministry of Health (MoH) to reduce nationwide neonatal mortality immensely by 2018. The health management teams in the districts and sub-districts adopting the strategy of targeting women with previous foetal deaths and facilitating their regular health check-ups in the appropriate health facilities would help reduce neonatal mortality not only in Kintampo Districts but other districts with similar characteristics.

Higher socio-economic status of households in the Kintampo Districts appears to be important for the reduction in risk of neonatal mortality. Since higher socio-economic status operates through several channels to reduce the risk of neonatal mortality, the multi-sectoral approach can be adopted to improve households' socio-economic status in the Kintampo Districts. One of these approaches is for the district directorate to partner NGOs to equip community members with income-generating skills and afterwards resource them by giving them capital to start small-scale businesses. This will result in generating income for their families to enable more pregnant women and mothers together with their newborns afford not just healthcare but quality healthcare to subsequently reduce the risk of neonatal mortality. Scaling up education on the need for pregnant women to attend antenatal clinics and the uptake of good nutrition in the sub-districts is another approach.

The study also found some significant clusters for premature and asphyxiated deaths. These clusters consist of villages from few sub-districts. For example, the cluster for premature births is made up of villages in Jema and Anyima sub-districts. The activities of the sub-districts under which these villages fall can be scaled up by the district directorate in consultation with the Ghana Health Service to channel more resources (such as requisite drugs and midwives) there to reduce these cause-specific neonatal mortalities. Moreso, the health directorate could appeal to the district assemblies and other stakeholders to build CHPS compounds closer to these villages; or by providing these villages with improvised tricycle ambulance which can convey neonates who need prompt attention to the nearest health facilities; or poor road networks in these villages can be rehabilitated to forestall the delay of reaching the health facility. Pregnant women can also be educated on neonatal danger signs that needs prompt attention by districts and sub-districts' health workers. These health workers can also train TBAs to advise pregnant women in their villages about the essence of delivering at the health facility. Mothers of premature babies can also be trained by districts and sub-districts' health workers on kangaroo mother care to reduce premature deaths.

Recommendations for Further Research

The findings of the study could not establish the mechanism through which household crowding operates to improve the chances of neonatal survival. This calls for further research to ascertain the influence of crowding on neonatal mortality. It would be appropriate to measure the size of household sleeping rooms and take that into account when estimating the crowding index.

This study suggests a lower risk of mortality for neonates who are delivered outside the hospital. There is, therefore, the need to conduct further research to understand why the risk of neonatal deaths outside the hospital is lower. It would be appropriate to triangulate both the qualitative and the quantitative approach to help understand this finding.

In addition, the study made an attempt to explain a higher risk of mortality among neonates belonging to mothers with middle, JHS or JSS education in comparison with those whose mothers did not have formal education. It will be appropriate to carry out further research using the mixed method approach to better understand this finding.

Purely spatial analysis for neonatal clustering was done by this work. However, spatio-temporal clustering was not done due to small numbers of neonatal deaths on a yearly basis. It will, therefore, be appropriate to carry out spatio-temporal clustering in the Kintampo Districts or similar setting to understand the mechanism that led to clustering.

BIBLIOGRAPHY

Aaby, P. (1987). *Overcrowding: a major determinant of variations in measles mortality in Africa*. IUSSP Seminar, Yaounde.

Abir, T., Ogbo, F. A., Stevens, G. J., Page, A. N., Abul, H. M., Agho, K. E. (2017). The impact of antenatal care, iron folic supplementation tetanus toxoid vaccination during pregnancy on child mortality in Bangladesh. *PLoS ONE, 2* (11), 1-14. Retrieved from https:// dhsprogram.com/ data/available-datasets.cfm.

Abdul-Mumin, A. & Gumanga, S. K. (2016). Neonatal Tetanus in Northern Region, Ghana – A Case Report. *Prograduate Medical Journal of Ghana, 5* (1), 42-44.

Adekanmbi, V. T., Kayode, G. A., & Uthman, O. A. (2011). Individual and contextual factors associated with childhood stunting in Nigeria: a multilevel analysis. *Maternal and Child Nutrition*, 9 (2), 244-259.

Adedini, S. A., Odimegwu, C., Imasiku, E. N. S., Ononokpono, D. N., Ibisomi, L. (2015). Regional variations in infant and child mortality in Nigeria: a multilevel analysis. *J Biosoc. Sci., 47*, 165-187.

Adjei, G., Enuameh, Y., Asante, K. P., Baiden, F., Nettey, O. E. A., Abubakari, S., … Owusu-Agyei, S. (2015). Predictors of abortion in Rural Ghana: a cross-sectional study. *BMC Public Health, 15*, 202-209. doi: 10.1186/s12889-015-1572-1.

Adjuik, M., Kanyomse E., Wak, G., Hodgson, A. (2010). Clustering of under-five mortality in Narong HDSS in the Kassena-Nankana District of Northern Ghana. *Global Health Action*, 3 (supp. 1), 15-25. doi:10.3402 /gha. v3i0.5233.

Adongo, P. B., Phillips, J. F., Kajihara, B., Fayorsey, C., Debpuur, C., Binka, F. N. (1997). Cultural factors constraining the introduction of family planning among the Kassena-Nankana of the Northern Ghana. *Soc. Sci. Med*, *45* (12), 1789-1804.

Afolabi, B. M. (2017). Sub-Saharan African Neonates – Ghosts to statistics. *J Neonatal Biol, 6* (1), 1-3. doi: 10.4172/2167-0897.1000246.

Ahsan, K. Z., Arifeen, S. E., Al-Mumun, M. A., Khani, S. H., Chakraborty, N. (2017). Effects of individual, household and community characteristics on child nutritional status in the slums of urban Bangladesh. *Archives of Public Health, 75*, 9-21. doi: 10.1186/s13690-017-0176-x.

Ajaari, J., Masanja, H., Weiner, R., Abokyi, S. A., Owusu-Agyei, S. (2012). Impact of place of delivery on neonatal mortality in rural Tanzania. *International Journal of MCH and AIDS, 1* (1), 49-59. Retrieved from www.mchandaids.org.

Akinyemi, J., O., Bamgboye, E. A., & Ayeni, O. (2015). Trends in neonatal mortality in Nigeria and effects of bio-demographic and maternal characteristics. *BMC Pediatrics, 15,* 1-12. doi: 10.1186/s12887-015-0349-0

Alabi, O., Baloye, D., Doctor, H. V., Oyedekun, O. A. (2016). Spatial Analysis of Under-five Mortality Clustering in Northern Nigeria: Findings from Nahuche Health and Demographic Surveillance System, Zamfara State. *International Journal of Tropical Disease & Health, 15* (1), 1-10. doi: 10.9734/IJTDH/2016/24709.

Alderman, H., Hentschel, J., & Sabates, R. (2003). With, the help of one's neighbours: externalities in the production of nutrition in Peru. *Soc Sci Med, 56*, 2019-2031.

Allison, P. D. (2014). *Event History and Surival Analyis*. Pennsylvania, USA: Sage Publications Inc.

Alosaimi, A. N., Luoto, R., Serouri, A. W. A., Nwaru, B. I., Mouniri, H. (2015). Measures of Maternal Socioeconomic Status in Yemen and Association with Maternal and Child Health Outcomes. *Matern Child Health J, 20* (2), 386-397. doi: 10.1007/s10995-015-1837-4.

Ameida, M. C. S., Gomes, C. M. S., & Nascimento, L. F. C. (2014). Spatial analysis of neonatal mortality in the state of São Paulo, 2006-2010. *Rev Paul Pediatr., 32* (4), 374-380. Retrieved from http://dx.doi.org/10.1016/j.rpped.2014.01.001.

Andres, L. A., Briceno, B., Chase, C., Echenique, J. A. (2014). *Santation and externalities: evidence from early childhood health in India*. Policy Research Working Paper No. WPS 6737. Washinton DC, USA: World Bank Group.

Andrzejewski, C. S., Reed, H. E., & White, M. J. (2009). Does where you live influence what you know? Community effects on health knowledge in Ghana. *Health and Place, 15,* 228-238.

Annan, G. N. & Asiedu, Y. (2018). Predictors of Neonatal Deaths in Ashanti Region of Ghana: A Cross-Sectional Study. *Advances in Public Health, 2018*, 1-11. Retrieved from https://doi.org/10.1155/2018/9020 914

Annett, A. (2001). Social Fractionalization, Political Instability, and the Size of Government. *IMF Staff Papers, 48* (3), 561–92.

Arku, R. E., Bennett, J. E., Castro M. C, Agyeman-Duah, K., Mintah S. E., Ware J. H., Ezzati, M. (2016). Geographical Inequalities and Social and Environmental Risk Factors for Under-Five Mortality in Ghana in 2000 and 2010: Bayesian Spatial Analysis of Census Data. *PLoS Med, 13* (6), 1-14. doi: 10.1371/journal.pmed.100203

Arguillas, M. (2008). *A Multilevel Analysis of the Community and Household Determinants of Child Mortality in Metro Cebu*, the Philippines. Ph.D. Thesis, Cornell University: New York, United States

Ayele, D. G., Zewotir, T. T., & Mwambi, H. (2017). Survival analysis of under-five mortality using Cox and frailty models in Ethiopia. *Journal of Health, Population and Nutrition, 36*, 1-9. doi: 10.1186/s410 43-017-0103-3

Babalola, S., Fatusi, A. (2009). Determinants of use of maternal health services in Nigeria-looking beyond individual and household factors. *BMC Pregnancy and Childbirth, 9*, 43-56. doi:10.1186/1471-2393-9-43

Baiden F., Hodgson A., Adjuik M., Adongo P., Ayaga B., Binka, F. (2006). Trend and causes of neonatal mortality in the Kassena-Nankana district of northern Ghana, 1995–2002. *Trop Med Int Health, 11* (4), 532–539.

Barreto, M. L., Genser, B., Strina, A. (2007). Effect of city-wide sanitation programme on reduction in rate of childhood diarrhea in northeast Brazil: assessment by two cohort studies. *Lancet, 370*, 1622-28.

Bashir, A. O., Ibrahim, G. H., Bashier, I. A., Adam, I. (2013). Neonatal mortality in Sudan: analysis of the Sudan household survey, 2010. *BMC Public Health, 13*, 287. Retrieved from http://www.biomed central.com/1471-2458/13/287

Baqui, A. H, Ahmed, S., Arifeen, S. E., Darmstdt, G. L., Rosecrans, A. M., Mannan, I., … Black, R. E. (2009). Effect of timing of first postnatal care home visit on neonatal mortality in Bangladesh: a observational cohort study. *BMJ, 2009*, 1-6. doi:10.1136/bmj. b2826

Belachew, A. B., Kahsay, A. B., & Abebe, Y. G. (2016). Individual and community-level factors associated with introduction of prelacteal feeding in Ethiopia. *Archives of Public Health, 74*, 1-11. doi: 10.1186/s13690-016-0117-0

Berhan, Y. & Berhan, A. (2014). A meta-analysis of selected maternal and fetal factors for perinatal mortality. *Ethiop J. Health Sci.*, 24, 55-68**.** Retrieved from http://dx.doi.org/10.4314/ejhs.v24i1.6S

Bhatacherjee, A., (2012). *Social Science Research: Principles, Methods, and Practices*. *Textbooks Collection.* Book 3. Retrieved from http://scholarcommons.usf.edu/oa_textbooks/3

Biering-Sorensen, S., Aaby, P., Napirna, B., M., Roth, A., Ravn, H., Rodrigues, A., … Benn, C. S. (2012). Small randomised trial among low-birthweight children receiving bacillus calmette -guerin vaccination at first health centre contact. *The Pediatric Infectious Disease Journal, 31* (3), 306-8.

Blencowe, H., Cousens, S., Chou, D., Oestergaard, M., Say, L., Moller, A., … Lawn, J. (2013). Born Too Soon: The Global Epidemiology of 15 million preterm births. *Reproductive Health*, 10 (Sup 1), 1-14. Retrieved from http://www.reproductive-health-journal.com/content/ 10/S1/S2

Blencowe, H., lawn, J., Vandelaer, Roper, M., Cousens, S. (2010). Tetanus toxoid immunization to reduce mortality from neonatal tetanus. *International Journal of Epidemiology, 39*, 102-109. doi:10.1093/ije/ dyq027

Bloom, S. S., Wypij, D. & Gupta. M. D. (2001). Dimensions of women's autonomy and the influence on maternal health care utilization in a North Indian City. *Demography 38*, 67-78.

Boco A. G. (2010). *Individual and community-level effects on child mortality: An analysis of 28 demographic and health surveys in sub-Saharan Africa*. DHS Working Papers No. 73. Calverton, Maryland: ICF Macro.

Brockerhoff, M., & Hewett, P. (2000). Inequality of child mortality among ethnic groups in sub-Saharan Africa. *Bulletin of the World Health Organisation*, *78* (1), 30-41.

Broom, A. & Willis, E. (2007). *Competing Paradigms and Health Research*. London: Sage Publication.

Buli, E. D. (2013). *Determinants of child survival chances in rural Ethiopia*. Proceedings 59th ISI World Statistics Congress, Hong Kong. Retrieved from http://2013.isiproceedings.org/Files/CPS105-P2-S.pdf

Buor, D. (2003). Mother's education and child mortality in Ghana. *Health Policy*, *64*, 297-309.

Buttenheim, A. M. (2008). The sanitation environment in urban slums; implications for child health. *Popul Environ*, *30*, 26-47.

Byass, P., Fantahun, M., Emmelin, A., Molla, M., Berhane, Y. (2010). Spatio-temporal clustering of Mortality in Butajira HDSS, Ethiopia, from 1987 to 2008. *Global Health Action*, *3* (1), 26-31. doi: 10.3402/gha. v3i0. 5244.

Cavazos-Rehg, P. A., Kraus, M. J., Spitznagel, E. L., Gomarite, K., Madden, T., Olsen, M. A., Bierut, L. J. (2015). Maternal age and risk of labour and delivery complications. *Maternal Child Health J.*, 19 (6), 1202-1211. doi:10.1007/s10995-014-1624-7

Chilisa, B. & Kawulich, B. (2011). *Selecting a research approach: paradigm, methodology and methods*. Retrieved from https://www.academia.edu/.../Selecting_a_research_approach_Paradigm_methodology.pdf

Chinkhumba, J., De Allegri, M., Muula, A. S., Robberstad, B. (2014). Maternal and perinatal mortality by place of delivery in sub-Saharan Africa: a meta-analysis of population-based cohort studies. *BMC Public Health*, 14, 1-9. doi:10.1186/1471-2458-14-1014

Corsi, D. J., Chow, C. K., Lear, S. A., Rahman, M. O., Subramanian, S. V., Teo, K. K (2011). Shared environments: A multilevel analysis of community context and child nutritional status in Bangladesh. *Public Health Nutr, 14*, 951-959.

Cox, D. R. (1972). Regression models and life-tables. *Journal of the Royal Statistical Society, 34*, 187–220.

Cramer, J. C. (1987). Social factors and infant mortality: identifying high-risk groups and proximate causes. *Demography, 24* (3), 289-321.

Crane, J. (1991). The Epidemic Theory of Ghettos and Neighborhood Effects on Dropping out and Teenage Childbearing. *AJS, 96* (5), 1226-59. doi: 128.135.012.127

Cunnington, A. J. (2001). What's so bad about teenage pregnancy? *Journal of Family Planning and Reproductive Health Care, 27*, 36–41.

Debelew, G. T., Afework, M. F., & Yalew, A. W. (2014). Determinants and causes of neonatal mortality in Jimma Zone, Southwest Ethiopia: a multilevel analysis of prospective follow up study. *PLoS ONE, 9* (9), 1-11. doi: 10.1371/journal.pone.0107184.

Degefie, T., Amare, Y., & Mulligan, B. (2014). Local understandings of care during delivery and postnatal period to inform home based package of newborn care interventions in rural Ethiopia: a qualitative study. *BMC International Health and Human Rights, 14* (17), 1-6. Retrieved from http://www.biomedcentral.com/1472-698X/14/17

Demicheli, V., Barale, A. & Rivetti, A. (2015). Vaccines for women for preventing neonatal tetanus. *Cochrane Database of Systematic Reviews 2015* (7), 1-53. doi: 10.1002/14651858.CD002959.pub4

Dijk, I. K. V. (2018). Early-life mortality clustering in families: A literature review. *Population Studies, 73* (2), 1-21. doi: 10.1080/00324728.2018. 144 8434

Duncan, C., Jones, K. & Moon, G. (1998). Context, Composition and Heterogeneity: Using Multilevel Models in Health Research. *Soc. Sci. Med., 1*, 97-117.

Edmond, K., M., Kirkwood, B., R., Amenga-Etego, S., Owusu-Agyei, S., Hurt, L. S. (2007). Effect of early infant feeding practices on infection-specific neonatal mortality: an investigation of the causal links with observational data from rural Ghana. *Am J Clin Nutr., 86* (4), 1126-31.

Edmond, K., Quigley, M. A., Danso, S., Hurt, C., Owusu-Agyei, S., Kirkwood, B. R. (2008). Diagnostic accuracy of verbal autopsies in ascertaining the causes of stillbirths and neonatal deaths in rural Ghana. *Paediatric and Perinatal Epidemiology,22*, 417-429. doi: 10.1111/j.1365-3016.2008. 00962.x.

Eisele, T. P., Lindblade, K. A., Rosen, D. H., Odhiambo, F., Voluble, J. M, Slutsker, L. (2003). Evaluating the completeness of demographic surveillance of children less than five years old in Western Kenya: a capture-recapture approach. *Am J Trop Med Hyg, 69* (1), 92-97.

Ellen, I. G., Mijanovich, T. & Dillman, K., N. (2001). Neighborhood Effects on Health: Exploring the Links and Assessing the Evidence. *Journal of Urban Affairs, 23*, 391-408.

Engmann, C., Welaga, P., Aborigo, R. A., Adongo, P., Moyer, C. A., Lavasani, L., … Hodgson, A. (2012). Stillbirths and early neonatal mortality in rural Northern Ghana. *Tropical Medicine and International Health*, 17 (3), 272-282. doi:10.1111/j.1365-3156.2011.02931. x.

Ezeh, O. K., Agho, K. E., Dibley, M. J., Hall, J., Page, A. N. (2014). Impact of water and sanitation on childhood mortality in Nigeria: Evidence from Demographic and Health Surveys, 2003-2013. *Int. J. Environ. Res. Public Health*, *11*, 9256-9272.

Fearon, J. D. (2003). Ethnic and cultural diversity by country. *Journal of Economic Growth, 8*, 195-222.

Fikree, F. F. (1993). Crowding a risk factor for perinatal mortality. *JPMA, 43*, 230-232.

Filmer, D. & Pritchett, H. L. (2001). Estimating wealth effects without income of expenditure data – or tears: an application to educational enrolments in States of India. *Demography,* 38 (1), 115–32.

Fink, G., Gunther, I. & Hill, K. (2011). The effect of water and sanitation on child health: evidence from the Demographic and Health Surveys 1986-2007. *International Journal of Epidemiology, 40*, 1196-1204. doi:10.1093/ije/dyr102

Fotso, J., & Kuate-Defo, B. (2005). Socioeconomic inequalities in early childhood malnutrition and morbidity: modification of household-level effects by community SES. *Health & Place, 11*, 205-225.

Fuller, J. A., Villamor, E., Cevallos, W., Trostle, J., Eisenberg, J. S. N. (2016). I get height with a little help from my friends: herd protection from sanitation on child growth from rural Ecuador. *International Journal of Epidemiology, 45* (2), 460-469.

Gabrysch, S., & Campbell, O. M. R. (2009). Still too far to walk: literature review of the determinants of delivery service use. *BMC Pregnancy and Childbirth, 9*, 1-18. doi:10.1186/1471-2393-9-34

Gabrysch, S., Cousens, S., Cox, J., Campbell, O. M. R. (2011). The influence of distance and level of care of delivery place in rural Zambia: a study of linked national data in a geographic information system. *PloS Med., 8* (1), 1-12. doi:10.1371/journal.pmed.1000394

Galster, G. C. (1986). What is neighbourhood? An externality-space approach. 243-263. *International Journal of Urban and Regional Research, 10*, 243-263.

Galster, G. (2001). On the Nature of Neighbourhood. *Urban Studies, 38*, 2111-2124. doi: 10.1080/00420980120087072

Galster, G. C. (2010). *The Mechanism(s) of Neighbourhood Effects: Theory, Evidence, and Policy Implications*. Scotland, UK. Retrieved from https://www.researchgate.net/publication/228614768_The_Mechanism_s_of_Neighborhood_Effects_Theory_Evidence_and_Policy_Implications

Ganle, J. K., Otupiri, E., Parker, M., Fitzpatrick, R. (2015). Socio-cultural barriers to accessibility and utilization of maternal and newborn healthcare in Ghana after user-fee. *International Journal of Maternal and Child Health, 3* (1), 1-14. doi: 10.12966/ijmch.02.01.2015

Gething, P. W., Johnson, F. A., Frempong-Ainguah, F., Nyarko, P. , Baschieri, A., Aboagye, P., … Atkinson, P. M. (2012). Geographical access to care at birth in Ghana: a barrier to safe motherhood. *BMC Public Health, 12*, 1-13. Retrieved from http://www.biomedcentral.com/1471-2458/12/991

Ministry of Health ((2014). *Ghana National Newborn Health Strategy and Action Plan 2014-2018: A Roadmap to Reduce Neonatal Deaths nationwide. Ghana*. Health Service, UNICEF, WHO & PATH, Ghana. Retrieved from https://www.healthynewbornnetwork.org/hnn-content/uploads/Ghana_Newborn_Flyer-FINAL.pdf

Ghana Statistical Service, Ghana Health Service & ICF Macro. (2009). *Ghana Demographic and Health Survey 2008*. Accra, Ghana: GSS, GHS, and ICF Macro.

Ghana Statistical Service (GSS) & United Nations Development Programme (UNDP) (2013). *Ghana Population and Housing Census 2010*. GSS and UNDP.

Ghana Statistical Service, Ghana Health Service & ICF International (2015). *Ghana Demographic and Health Survey 2014*. Rockville, Maryland, USA: GSS, GHS, and ICF International.

Goldenberg, R. L., Culhane, J. F., Iams, J. D., Romero, R. (2008). Epidemiology and causes of preterm birth. *Lancet*, *371 (9606), 75*-84. doi: 10.1016/S0140-6736(08)60074-4

Golding, J., Greenwood, R., McCaw-Binns, A., Thomas, P. (1994). Associations between social and environmental factors and perinatal mortality in Jamaica. *Paediatric and Perinatal Epidemiology, 8* (Supp. 1), 17-39.

Gopalan, S. (2000). Malnutrition: Causes, Consequences and Solutions. *Nutrition*, *16*, 7-8.

Gordon, R. A., Savage, C., Lahey, B. B., Goodman, S. H., Jensen, P. S., Rubio-Stipec, M., Hoven, C. W. (2003). Family and Neighborhood income: additive multiplicative associations with youth's well-being. *Social Science Research, 32*, 191-219.

Grady, S. C., Frake, A. N., Zhang, Q., Bene, M., Jordan, D. R., Vertalka, J., … Kutch, L. (2017). Neonatal mortality in East Africa and West Africa: a geographic analysis district-level demographic and health survey data. *Geospatial Health, 12*, 137-150. doi:10.4081/gh.2017.501

Grambsch, M., & Therneau, T. M. (1994). Proportional hazards tests and diagnostics based on weighted residuals. *Biometrika, 81* (3), 515-526.

Griffiths, P., Madise, N., Whitworth, Matthews, A. (2004). A tale of two continents: a multilevel comparison of the determinants of child nutritional status from selected African countries and Indian regions. *Health & Place, 10*, 183-199.

Guba, E. G. & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. K. Denzin & Y. S. Lincoln, Handbook *of qualitative research*, 3rd Edn. (pp. 105 – 117). California: Sage Publication.

Gunther, I., & Fink, G. (2010). *Water, sanitation and children's health: evidence from 172 countries*. Policy Research Working Paper No. 5275, The World Bank Development Economics Prospects Group. Retrieved from http://documents.worldbank.org/curated/en/630921468151763344/pdf/WPS5275.pdf

Gutierrez, R. G. (2002). Parametric frailty and shared frailty survival models. *Stata Journal 2*, 22–44.

Gyimah, S. O., (2002a). The dynamics of spacing and timing of births in Ghana. *PSC discussion papers series, 16* (4), 1-34. Retrieved from http://www.ssc.uwo.ca/sociology/popstudies/dp/dp02-04.pdf

Gyimah, S. O., (2002b). Ethnicity and infant mortality in sub-Saharan Africa: the case of Ghana. *PSC discussion papers series, 16* (10), 1-30. Retrieved from http://ir.lib.uwo.ca/pscpapers/vol16/iss10/1

Harris, M., Alzua, M. L., Osbert, N., Pickering, A. (2017). Community-level sanitation coverage more strongly associated with child growth and household drinking water quality than access to a private toilet in rural Mali. *Environmental Science & Technology, 51*, 7219-7227.doi: 10.1021/acs.est. 7b00178

Heffner, L. J. (2004). Advanced Maternal Age – How Old is Too Old? *N Eng J Med, 351*, 19-21.

Howson, C. P., Kinney, M. V., & Lawn, J. E., (2012). *The global action report on preterm births*. March of Dimes, PMNCH, Save the Children, WHO, Geneva.

Huda, T. M., Tahsina, T. Arifeen, S. E., Dibley, M. J. (2016). The importance of intersectoral factors equity-oriented universal health coverage: a multilevel analysis of social determinants affecting neonatal, infants and under-five mortality in Bangladesh. *Global Health Action, 9*, 1-14.

Hug, L., Sharrow, D., Sun, Y., Marcusanu, A., You, D. (2017). Levels & Trends in Child Mortality Report 2015. UNICEF, WHO, World Bank Group, UN.

Ibrahim, S. A., Babikert, A. G., Amin, I. K., Omer, M. I. A., Rushwan, H. (1994). Factors associated with high risk of perinatal and neonatal mortality: an interim report on a prospective community-based study in rural Sudan. *Paediatric and Perinatal Epidemiology*, *8*, 193-204.

Jejeebhoy, S. (1998). Associations between wife-beating and fetal and infant death: impression from a survey in rural India. *Studies in family Planning, 29*, 301-308.

Johnson, F. A., Frempong-Ainguah, F., Matthews, Z., Harfoot, A. J. P., Nyarko, P., Baschieri, A., … Atkinson, P. M. (2015). Evaluating the impact of the Community-Based Health Planning and Services initiative on uptake of skilled birth care in Ghana. *PLoS ONE, 10* (3), 1-18. doi:10.1371/ journal. pone.0120556

Kamal, S. M. M. (2012). Maternal education as a determinant of neonatal mortality in Bangladesh. *Journal of Health Management, 14* (3), 269-281.

Kamal, S. M. M. (2015). Between maternal age and neonatal mortality? An analysis of the 2007 Bangladesh Demographic and Health Survey. *Asia-Pacific Journal of Public Health, 27* (2),1107-118. doi: 10.1177/101053 9511428949

Kananura, R., M., Tetui, M., Mutebi, A., Bua, J., N., Waiswa, P., Kiwanuka, S., N., … Makumbi, F. (2016). The neonatal mortality and its determinants in rural communities of Eastern Uganda. *Reprod Health, 13*, 1-9. doi: 10.1186/s12978-016-0119-y

Karra, M., Fink, G., & Canning, D. (2016). Facility distance and child mortality: a multi-country study of health facility access, service utilization, and child health outcomes. *International Journal of Epidemiology*, 46 (3), 817-826. doi: 10.1093/ije/dyw062

Kashima, S., Suzuki, E., Okayasu, T., Louis, R. J., Eboshida, A., Subramanian, S. V. (2012). Association between proximity to a health centre and early childhood mortality in Madagascar. *PLoS ONE*, *7* (6), 1-8.

Kayode, G. A., Ansah, E., Agyepong, I. R., Amoakoh-Coleman, M., Grobbee, D. E., Klipstein-Grobusch, K. (2014). Individual and community determinants of neonatal mortality in Ghana: a multilevel analysis. *BMC Pregnanacy and Child Birth, 14*, 1-12. doi: http://www.biomedcentral. com/1471-2393/ 14/165

Kayode, G., A., Grobbee, D. E., Amoakoh-Coleman, M., Ansah, E., Uthman, O. A., Klipstein-Grobusch, K. (2017). Variation in neonatal mortality and its relation to country characteristics in sub-Saharan Africa: an ecological study. *BMJ Global Health, 2*, 1-7.

Khadka, K. B., Lieberman, L. S., Giedraitis, V., Bhatta, L., Pandey, G (2015). The socio-economic determinants of infants mortality in Nepal: analysis of Nepal Demographic Health Survey, 2011. *BMC Pediatrics, 15*, 152-162. doi: 10.1186/s12887-015-0468-7

Kikuchi, K., Ansah, E., Okawu, S., Shibanuma, A., Gyapong, M., Owusu-Agyei, S., … Jimba, M. (2015). Ghana's Ensure Mothers and Babies Regular Access to Care (EMBRACE) program: study protocol for a cluster randomized controlled trial. *Trials, 16*, 22-35. doi: 10.1186/s1 3063-014-0539-3.

Kim, D. & Saada, A. (2013). The Social Determinants of Infant Mortality and Birth Outcomes in Western Developed Nations: A Cross-Country Systematic Review. *Int. J. Environ. Res. Public Health, 10,* 2296-2335. doi:10.3390/ijerph10062296.

Kirkwood, B., R., Manu, A., ten Asbroek, A., H., Soremekun, S., Woebong, B., Gyan, T. et. al. (2013). Effect of the Newhints home-visits intervention on neonatal mortality rate and care practices in Ghana: a cluster randomised control trial. *Lancet*, *381* (9884), 2184-2192. doi: 10.1016/S0140-6736(13)60095.

Klein, J. D. (2005). Adolescent pregnancy: current trends and issues. *Pediatrics, 116*, 281–286.

Kohler, H. P., Behrman, J. R. & Watkins, S. C. (2001). The density of social networks and fertility decisions: Evidence from South Nyanza district, Kenya. *Demography, 38*, 43-58.

Kolola, T, Ekubay, M., Tesfa, E., Morka, W. (2016). Determinants of Neonatal Mortality in North Shoa Zone, Amhara Regional State, Ethiopia. *PLoS ONE, 11* (10), 1-11. doi: 10.1371/journal.pone.0164472.

Kozuki, N., Lee, C. C., Silveira, M. F., Sania, A., Vogel, J. P., Adair, L., Katz, J. (2013). The associations of parity and maternal age with small-for-gestational-age, preterm and neonatal and infant mortality: a meta-analysis. *BMC Public Health, 13,* 1-10. Retrieved from http://www.Biomedcentral .com/1471-2458/13/S3/S2.

Kramer, M. S., Seguin, Lydon, L., Goulet, L. (2000). Socio-economic disparities in pregnancy outcome: why do the poor fare so poorly? *Paediatric and Perinatal Epidemiology, 14*, 194-210.

Kravdal, O. (2004). Child mortality in India: the community-level effect of education. *Population Studies: A Journal of Demography, 52* (2), 177-192. doi: 10.1080/0032472042000213721.

Kuate-Defo, B., & Diallo, K. (2002). Geography of child mortality clustering within African families. *Health & Place, 8*, 93-117.

Kujala, S., Waiswa, P., Kadobera, D., Akuze, J., Pariyo, G., Hanson, C. (2017). Trends and risk factors of stillbirths and neonatal deaths in Eastern Uganda (1982-2011): a cross-sectional, population-based study. *Tropical Medicine and International Health, 22* (1), 63-73. doi:10.1111/tmi.12807.

Kumar, C., Singh, K. M., Rai, R. K., Singh, L. (2013). Early neonatal mortality in India, 1990-2006. *J Community Health, 38*, 120-130. doi: 10.1007/s 10900-012-9590-8.

Kumar, S., Dansereau, E. A., & Murray, J. L. (2014). Does distance matter for institutional delivery in rural India? *Applied Economics, 46* (33), 1-14.

Kwaraji, Y. B., Cousens S., Berhane Y., Mulholland K., Edmond, K. (2012). Effect of Geographical Access to Health Facilities on Child Mortality in Rural Ethiopia: A Community Based Cross Sectional Study. *PLoS ONE 7* (3), 1-8. doi: 10.1371/journal.pone.0033564.

Kyu, H. H., Mumford, J. E., Stanaway, J. D., Barber, R. M., Hancock, J. R., Vos, T., Naghavi, M. (2017). Mortality from tetanus between 1990 and 2015: findings from the global burden of disease study 2015. *BMC Public Health, 17*, 179-196. doi: 10.1186/s12889-017-4111-4.

Lalou, R. (1997). *Endogenous mortality in France: at the crossroads of natural and social selection*. Oxford: Clarendon Press.

Lambon-Quayefio, M. & Owoo, N. S. (2017). Determinants and Impact of National Health Insurance on Neonatal Mortality in Ghana. *Health Economics Review, 7*, 34-50. doi: 10.1186/s13561-017-0169-z.

Larsen, D. A., Grisham, T., Slawsky, E., Narine, L. (2017). An individual meta-analysis assessing the impact of community-level sanitation access on child stunting, anaemia, and diarrhea: evidence from DHS and MICS surveys. *PLoS Negl Trop Dis, 11* (6), 1-13.

Lawn, J. E., Cousens, S., Zupan, J. (2005). 4 million neonatal deaths: when? where? why*?* *Lancet*, 365 (9462), 891–900. Retrieved from http://dx.doi.org/10.1016/S0140-6736(05)71048-5.

Lawn J., Kerber K., editors (2006). *Opportunities for Africa's Newborns: practical data, policy and programmatic support for newborn care in Africa*. Cape Town, South Africa: PMNCH, Save the Children, UNFPA, UNICEF, USAID, WHO.

Lawn J., Mongi, P. & Cousens S. (2011). *Africa's newborns - counting them and making them count.* Opportunities for Africa's Newborns. Retrieved from https://www.who.int/pmnch/media/publications/aonsection_I.pdf

Lin, D. Y. & Wei, L. J. (1989). The robust inference for the Cox proportional hazards model. *Journal of the American Statistical Association, 84,* 1074–1078.

Liu, L., Oza, S., Hogan, D., Perin, J., Rudan, I., Lawn, J. E. , Black, R. E. (2014). Global, regional, and national causes of child mortality in 2000-13, with projections to inform post-2015 priorities: an updated systematic analysis. *Lancet*, *385* (9966), 430-440. Retrieved from http://dx.doi.org/10. 1016/S0140-6736(14)61698-6.

Liu, L., Johnson, H. L., Cousens S., Perin J., Scott S., Lawn J. E., … Li, M. (2012). Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000. *Lancet*, 379 (9832), 2151–61. Retrieved from http://dx.doi.org/10.1016/S0140-6736 (12)60560-1

Liwin, L. K. & Houle, B. (2019). The effects of household and community contexts on mortality among children under-five in Sierra Leone: Evidence from the 2013 Demographic and Health Survey. *Demographic Research, 40* (11), 279-306. doi: 10.4054/ DemRes.2019.40.11.

Lutambi, A. M., Alexander, M., Charles, J., Mahutanga, C., Nathan, R. (2010). Under-five mortality: Spatial-temporal clusters in Ifakara HDSS in South-Eastern Tanzania. *Global Health Action*, 3 (sup 1), 32-41. doi: 10.3402 /gha.v3i0.5254

Macassa G., Ghilaghaber G., Bernhardt E., Burström, B. (2004). Contribution of household environment factors to urban childhood mortality in Mozambique. *East African Medical Journal*, 81, 408-414.

Malqvist, M. (2011). Neonatal Mortality: an invisible and marginalised trauma. *Global Health Action*, 4, 1-11. doi: 10.3402/gha. v4i0.5724.

Malqvist, M., Sohel, N., Do, T. T., Eriksson, L., Persson, L. (2010). Distance decay in delivery care utilisation associated with neonatal mortality. A case referent study in northern Vietnam. *BMC Public Health, 10,* 1-9.

Manda, S. O. M. (2001). A comparison of methods for analysing a nested frailty model to child survival in Malawi. *Aust. N. Z. J. Stat, 43* (1), 7-16.

Maniruzzaman, M., Suri, H. S., Kumar, N., Abedin, M. M., Rahman, M. J., El-Baz, …, Suri, J. S. (2018). Risk factors of neonatal mortality and child mortality in Bangladesh. *Journal of Global Health, 8* (1), 1-16. doi: 10.7189/jogh.08.010421.

Manortey, S., Carey A., Ansong, D., Harvey, R., Good, B., Boaheng, J. et. al. (2011). Verbal autopsy: an analysis of the common causes of childhood death in the Barekese sub-district of Ghana. *J Public Health Afr., 33* (5), 261-262.

Marchant, T., Willey, B., Katz J., Clarke S., Kariuki, S., ter Kuile, F., … Schellenberg, J. A. (2012). Neonatal mortality risk associated with preterm birth in East Africa adjusted by weight for gestational age: individual participant level meta-analysis. *PLoS Med, 9* (8), 1-13. doi: 10.1371/journal.pmed.1001292.

Masters, S. H., Burstein, R., Amofah, G., Abaogye, P., Kumar, S., Hanlon, M (2013). Travel time to maternity care and its effect on utilization in rural Ghana: a multilevel analysis. *Social Science & Medicine, 93,* 147-154.

Matteson, D. W., Burr, J. A. & Marshall, J. R. (1998). Infant Mortality: A Multi-level of Individual and Community Risk Factors. *Soc. Sci. Med., 47* (11), 1841-1854.

Mckinnon, B., Harper, S., Kaufman, J., S., Abdullah, M. (2014). Distance to emergency obstetric services and early neonatal mortality in Ethiopia. *Tropical Medicine and International Health, 19 (7)*, 780-790. doi:10.11 11/tmi.12323.

Mekonnen, Y., Tensou B., Telake D. S., Degefie, T., Bekele, A (2013). Neonatal mortality in Ethiopia: trends and determinants. *BMC Public Health, 13*, 1-14. Retrieved from http://www.biomedcentral.com/1471-2458/13/483

Merlo, J., Yang, M., Chaix, B., Lynch, J., Rastam, L. (2005). A brief conceptual tutorial on multilevel analysis in social epidemiology: investigating contextual phenomena in different groups of people. *J Epidemiol Community Health, 59*, 729-736. doi: 10.1136/ jech.2004.023929

Ministry of Health, Ghana (2014). *Under Five's Child Health Policy: 2007-2015*. Ghana Health Service, Ghana. Retrieved from https://extranet. who.int/ nutrition/gina/sites/default/files/GHA%202007%20Under%20Five%27s% 20Child%20Health%20Policy%202007%20-%202015.pdf

Mmusi-Phetoe, R. M. M. (2016). Social factors determining maternal and neonatal factors in South Africa: A qualitative study. *Curationis 39* (1), 1-8. Retrieved from htp://dx.doi.org/10.4102/curatonis.v39i1.1571

Mosley, W. H. & Chen, L. C. (1984). An Analytical Framework for the study of Child Survival in Developing Countries. *Population and Development Review, 10*, 25-45. Retrieved from http://www.jstor.org/stable/2807954.

Moyer, C., Dako-Gyeke, P. & Adanu, R. (2013). Facility-based delivery and maternal and early neonatal mortality in sub-Saharan Africa: A regional review of the literature. *African Journal of Reproductive Health, 17* (3), 30-43.

Muglia, L. J. Katz, M. (2010). The enigma of spontaneous preterm birth. *N Engl J Med, 362* (6), 529-535. doi: 10.1056/NEJMra0904308

Mugo, N., S., Agho, K. E., Zwi, A. B., Damundu, E. Y., Dibley, M. J. (2018). Determinants of neonatal, infant and under-five mortality in a war-affected country: analysis of the 2010 Household Health Survey in South Sudan. *BMJ Global Health, 3*, 1-16. doi:10.1136/bmjgh-2017-000510

Muhuri, P. K. & Preston, S. H. (1991). Effects of Family Composition on Mortality Differentials by Sex among Children in Matlab, Bangladesh. *Population and Development Review, 17* (3), 415-434. Retrieved from http://www.jstor.org/stable/1971948

Nankabirwa, V., Tumwine, J. K., Mugaba, P. M., Tylleskar, T., Sommerfelt, H. (2015). Child survival and BCG vaccination: a community based prospective cohort study in Uganda. *BMC Public Health, 15* (175), 1-10. doi: 10.1186/s12889-015-1497-8.

Nasejje, J. B., Mwambi, H. G., & Achia, T. N. (2015). Understanding the determinants of under-five child mortality in Uganada including the estimation of unobserved household and community effects using both frequentist and Bayesian analysis approaches. *BMC Public Health*, *15*, 1003-1015. doi: 10.1186/s12889-015-2332-y.

Nathan, R. & Mwanyangala, M. A. (2012). Survival of neonates in rural Southern Tanzania: does place of delivery or continuum of care matter? *BMC Pregnancy Childbirth, 12*, 1-7. doi:10.1186/1471-2393-12-18

Nesbitt, R. C., Lohela, T. J., Soremekun, S., Vesel, L., Manu, A., Okyere, E., … Gabrysch, S. (2016). The influence of distance and quality of care on place of delivery in rural Ghana. *Scientific Reports*, *6*, 1-8. doi: 10.1038/ srep30291.

Nettey, O. E. A., Zandoh, C., Sulemana, A., Adda, R., Owusu-Agyei, S. (2010). Clustering of childhood mortality in the Kintampo Health and Demographic Surveillance System in Ghana. *Global Health Action*, 3 (supp 1), 8-14. doi: 10.3402/gha.v3i0.5258.

Neupane, S. & Doku, T., K. (2014). Neonatal mortality in Nepal: A multilevel analysis of a nationally representative sample. *J Epidemiol Global Health*, *4*, 213-222. Retrieved from http://dx.doi.org/10.1016/j.jegh. 2014.02.001

Nisar, Y. B., & Dibley, M. J. (2014). Determinants of neonatal mortality in Pakistan: secondary analysis of Pakistan Demographic and Health Survey. *BMC Public Health*, 14, 1-12. Retrieved from http://www.biomed central. com/1471-2458/14/663.

Ntenda, P. A. M., Chuang, K., Tirunah, F. N., Chuang, Y. (2014). Factors associated with infant mortality in Malawi. *J Exp Clin Med, 6* (4), 125-131.

Nygren, B. L., O'Reilly, C. E., Rajasingham, A., Omore, R., Ombok, M., Awuor, A. O., … Mintz, E. D (2016). The Relationship between Distance to Water Source and Moderate-to-Severe Diarrhea in the Global Enterics Multi-Centre Study in Kenya, 2008-2011. *Am. J. Trop. Med Hyg. 94* (5), 1143-1149. doi:10.4269/ajtmh.15-0393

Okwaraji, Y. B., Cousens, S., Berhane, Y., Mulholland, K., Edmond, K. (2012). Effect of geographical access to health facilities on child mortality in rural Ethiopia: a community based cross sectional study. *PLoS ONE, 7* (3), 1-8. doi: 10.1371/journal.pone.0033564.

Omariba, D. W. R. (2004). Family level clustering of childhood mortality in Kenya. *PSC Discussion Paper Series, 18* (9), 1-46.

Omariba, D. W. R., Beaujot, R., & Rajulto, F. (2007). Determinants of infant and child mortality in Kenya. *Poul Res Policy Rev, 26*, 299-321. doi: 10.1007/ s11113-007-9031-z.

Osei, F. B. & Stein, A. (2017). Spatial variation and hot-spots of district level diarrhea incidences in Ghana: 2010-2014. *BMC Public Health, 17* (617), 1-10. doi 10.1186/s12889-017-4541-z.

Oswald, W. E., Stewart, A. E. P., Kramer, M. R., Endeshaw, T., Zerihun, M., Melak, B., … Moe, C. L. (2017). Association of community sanitation usage with soil-transmitted helminth infections among school-aged children in Amhara Region, Ethiopia. *Parasites and Vectors, 10,* 1-13. doi: 10.1 186/s13071-017-2020-0.

Owusu, B. A., Lim, A., Makaje, N., Wobil, P., SameAe, A. (2018). Neonatal mortality at the neonatal unit: the situation at a teaching hospital in Ghana. *Afri Health Sci.*, 18 (2), 369-377. Retrieved from https://dx.doi.org/ 10.4314/ahs.v18i2.22.

Owusu-Agyei, S., Nettey, O. E. A., Zandoh, C., Sulemana, A., Adda, R., Amenga-Etego, S., Mbacke, S. (2012). Demographic patterns and trends in Central Ghana: baseline indicators from the Kintampo Health and Demographic Surveillance System. *Global Health Action, 5,* 1-11.

Padilla, C. M., Kihal-Talantikit, W., Vieira, V. M., Deguen, S. (2016). City-Specific Spatiotemporal Infant and Neonatal Mortality Clusters: Links with Socioeconomic and Air Pollution Spatial Patterns in France. *Int. J. Environ. Res. Public Health, 13,* 1-21. doi:10.3390/ijerph 13060624

Pamuk, E. R., Fuchs, R. & Lutz, W. (2011). Comparing Relative Effects of Education and Economic Resources on Infant Mortality in Developing Countries. *Population and Development Review, 37* (4), 637-664. doi:10.1111/j.1728-4457.2011. 00451.x

Paudel, D., A., Thapa, A., Shedain, P. R., Paudel, B. (2013*). Trends and determinants of neonatal mortality in Nepal: Further analysis of the Nepal Demographic and Health Surveys, 2001-2011*. Calverton, Maryland, USA: Nepal Ministry of Health and Population, New ERA, and ICF International. Retrieved from https://dhsprogram.com/ pubs/pdf/FA75/FA75.pdf

Pebley, A. R. & Amin, S. (1991). The impact of a public-health intervention on sex differentials in childhood mortality in rural Punjab, India. *Health Transition Review, 1* (2), 143-169. Retrieved from http://www. jstor.org/ stable/40651705

Plunkett, J., Mulia, L. J. (2008). Genetic contributions to preterm birth: implications from epidemiological and genetic associations studies. *Ann Med, 40* (3), 167-95. doi: 10.1080/07853890701806181

Posner, D. N. (2004). Measuring ethnic fractionalization in Africa. *American Journal of Political Science, 48* (4), 849-863.

Quattrochi, J., Jasseh, M., Mackenzie, G., Castro, M., C., (2015). Spatial analysis of under-5 mortality and potential risk factors in the Basse Health and Demographic Surveillance System, the Gambia. *Tropical Medicine and International Health, 20* (7), 941-951. doi:10.1111/ tmi.12490.

Rahman, M., Rahman, M. M. & Wojtyniak, B. (1985). Impact of environmental sanitation and crowding on infant mortality. *Lancet, 2*, 28-31.

Rahman, M., & Abidin, S. (2010). Factors affecting neonatal mortality in Bangladesh. *Journal of Health Management, 12* (2), 137-152. doi:10.11 77/097206341001200203

Rahman, M. & Huq, S. (2009). Biodemographic and health seeking behaviour factors influencing neonatal and postneonatal mortality in Bangladesh: Evidence from DHS data. *East African Journal of Public Health, 6* (1), 77-84.

Ramaiya, A., Kiss, L., Baraitser, P., Mbaruku, G. (2013). A comparative analysis of first day neonatal mortality between adolescents and adult females giving birth at Ligula Hospital in Mtwara, South-Eastern Tanzania 2008-2009. *East African Medical Journal, 90* (11), 358-364.

Reid, A. (2001). Neonatal mortality and still births in early twentieth century, Derbyshire. *Population Studies, 55* (3), 213-232.

Roper, M. H., Vandelaer, J. H., & Gasse, F. L. (2007). Maternal and neonatal tetanus. *Lancet*, *370* (9603), 1947-1959.

Roux, A. V. D. (2001). Investigating Neighborhood and Area Effects on Health. *Am J Public* Health, *91*, 1783-1789.

Sankoh, O., Welaga, P., Debpuur, C., Zandoh, C., Gyaase, S., Poma, M. A., … Aaby, P. (2014). The non-specific effects of vaccines and other childhood interventions: the contribution of INDEPTH Health and Demographic Surveillance Systems. *International Journal of Epidemiology, 43 (3)*, 645-653. doi: 10.1093/ije/dyu101

Sankoh, O. A., Ye, Y., Sauerborn, R., Muller, O., Becher., H. (2001). Clustering of Child Mortality in Rural Burkina Faso. *International Journal of Epidemiology*, *30*, 485-492.

Sartorius, B. K. D., Kahn K., Vounatsou P., Collinson, M. A., Tollman, M. T. (2010). Young and vulnerable: Spatial-temporal trends and risk factors for infant mortality in rural south Africa (Agincourt), 1992-2007. *BMC Public Health*, *10*, 1-15. Retrieved from http://www.biomed central.com/ 1471-2458/10/645

Sartorius, B. K. D., Sartorius, K., Tobias, F. C., Chirwa, T. F. (2011). Infant mortality in South Africa - distribution, associations and policy implications, 2007: ecological spatial analysis. *International Journal of Health Geographics*, *10*, 1-13. Retrieved from http://www.ij-healthgeographics.com/content/10/1/61

Sastry, N. (1996). Community characteristics, individual and household attributes, and child survival in Brazil. *Demography, 33* (2), 211-229.

Sastry, N. (1997a). What explains rural-urban differentials in child mortality in Brazil*? Soc. Sci. Med., 44* (7), 989-1002.

Sastry, N. (1997b). Family-level clustering of childhood mortality risk in Northeast Brazil. Population Studies: *A Journal of Demography, 51* (3), 245-261. doi: 10.1080/0032472031000150036.

Sastry, N. (1997c). A Nested Frailty Model for Survival Data, With an application to the Study of Child Survival in Northeast Brazil. *Journal of the American Statistical Association, 92* (438), 426-436. Retrieved from http://www.jstor.org/stable/2965690

Say, L. & Raine, R. (2007). A Systematic Review of Inequalities in the Use of Maternal Health Care in Developing Countries: Examining the Scale of the Problem and the Importance of Context. *Bulletin of the World Health Organization, 85,* 812-819.

Selemani, M., Mwanyangala, M. A., Mrema, S., Shamte, A., Kajungu, D., Mkopi, A. ... Nathan, R. (2014). The effect of Mother's age and other related factors on neonatal survival associated with first and second birth in rural, Tanzania: evidence from Ifakara Health and Demographic Surveillance System in rural Tanzania. *BMC Pregnancy and Childbirth*, *14* (240), 1-9. Retrieved from http://www. biomedcentral.com/1471-2393/14/240

Shah, R., Mullany, L. C., Darmstadt, G. L., Talukder, R. R., Rahman, S. M., Mannan, I., … Baqui, A. H (2014). Neonatal mortality risks among preterm births among rural Bangladeshi cohort. *Paediatric and Perinatal Epidemiology, 28,* 510-520.

Sharma, R. K. (1997). Causal Pathways to infant mortality. *Journal of Health & Social Policy, 9* (3), 15-28. doi: 10.1300/J045v09n03_02.

Shell-Duncan, B., & Obiero, W. O. (2000). Child nutrition in the transition from nomadic pastoralism to settled lifestyles: individual, household and community-level factors. *American Journal of Physical Anthropology*, *113*, 183-200.

Schultz, T., P. (1984). Studying the Impact of Household Economic and Community Variables on Child Mortality. *Population and Development Review, 10*, 215-235.

Singh, A., Pallikadavath, S., Ogollah, R., Stones, W. (2012). Maternal tetanus toxoid vaccination and neonatal in rural North India. *PloS ONE, 7 (11)*, 1-8.

Singh, A., Kumar, A., & Kumar, A. (2013). Determinants of neonatal mortality in rural India. *PeerJ*, *1*, 1-26. doi: 10.7717/peerj.75.

Singh, K., Speizer, I., Handa, S., Boadu, R., O., Atinbire, S., Barker, P., M. (2013). Impact evaluation of a quality improvement intervention on maternal and child health outcomes in Northern Ghana: early assessment of a national scale-up project. *Int J Qual Health Care*, *25* (5), 477-87. doi: 10.109 3/intqhc/mzt054

Solar, O. & Irwin A. (2010). *A conceptual framework for action on the social determinants of health*. Social Determinants of Health Discussion Paper 2 (Policy and Practice). Retrieved from https://www.who.int/sdhconference/ resources/ConceptualframeworkforactiononSDH_eng.pdf

Stanton, C. K., Newton, S., Mullany, L. C., Cofie, P., Agyemang, C. T., Adiibokah, E., … Owusu-Agyei, S. (2012). Impact on postpartum hemorrhage of prophylactic administration of oxytocin 10 IU uniject by peripheral health care providers home births: design of a community-based cluster-randomized trial. *BMC Pregnancy & Childbirth, 12* (42), 1-10. Retrieved from http://www.biomed central.com/1471-2393/12/42

StataCorp LLC (2014). *Stata Survival Analysis Manual*. Texas, USA: Stata Press. Retrieved from https://www.stata.com/manuals14/st.pdf

Strait, J. B. (2006). An epidemiology of neighborhood poverty: causal factors of infant mortality among Blacks and Whites in the Metropolitan United States. *The Professional Geographer, 58* (1), 39-53.

Streiful, C. & Bliss, K. E. (2014). *Improving, maternal, Neonatal and Child Health in Ghana.* Centre for Strategic and International Studies, Ghana. Retrieved from https://csis-prod.s3.amazonaws.com/s3fs\public/legacy_ files/files/publication/141118_Bliss_ ImprovingHealthGhana_Web.pdf

Sutan, R., & Berkat, S. (2014). Does cultural practice affect neonatal survival- a case control study among low birth weight babies in Aceh Province, Indonesia. *BMC Pregnancy and Childbirth*, *14*, 1-13.

Taha, E. T., Gray, R. H. & Abdelwahab, M. M. (1993). Determinants of neonatal mortality in Central Sudan. *Annals of Tropical Paediatrics*, *13*, 4, 359-364. doi:10.1080/02724936.1993.11747671

Thaddeus, S., & Maine, D. (1994). Too far to walk: maternal mortality in context. *Soc. Sci. Med.*, *38* (8), 1091-1110.

Titaley, C. R., Dibley, M. J., Agho, K., Roberts, C. L., Hall, J. (2008). *BMC Public Health*, *8*, 1-15. doi:10.1186/1471-2458-8-232

Tura, G., Fantahun, M., & Worku, A. (2013). The effect of health facility delivery on neonatal mortality: systematic review and meta-analysis. *BMC Pregnancy & Childbirth*, *13* (18), 1-9.

Tymicki, K. (2009). Correlates of infant and child mortality: A theoretical overview and new evidence from the analysis of longitudinal of the Bejsce (Poland) parish register reconstitution study of the 18th-20th centuries. *Demographic Research*, *20* (23), 559-594. doi: 10.4054/DemRes.2009. 20.23

UNICEF (2015). *Ghana Internal Statistics Bulletin*. Retrieved from https://www. unicef.org/ghana/REALLY_SIMPLE_STATS_-_Issue_1(1).pdf

United Nations Children's Funds (2012). *The Structural Determinants of Child Well-being*. Retrieved from https://www.unicef-irc.org/publications/pdf/structural_determ_eng.pdf

United Nations Children's Funds (2014). *Committing to child survival: a promise renewed*. Retrieved from http://www.apromiserenewed.org

United Nations Children's Funds (2015). *Committing to child survival: a promise renewed*. Retrieved from http://www.apromiserenewed.org.

United Nations Children's Funds (2016). *From the first hour of life. Making the case of improved infants and young child feeding everywhere*. Data and Analytics, Division of Data, Research and Policy and Nutrition Section, Programme Division, United Nations Plaza, USA. Retrieved from http://data.unicef.org/topic/nutrition/infant-and-young-child-feeding/

United Nations (2015). *The Millennium Development Goals Report*. Retrieved from https://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20(July%201).pdf

Upadhyay, R. P., Rai, S. K., & Krishnan, A. (2012). Using the three delays model to understand the social factors responsible for neonatal deaths in rural Haryana, India. *Journal of Tropical Pediatrics*, *59* (2), 100-105. doi:10.1093/tropej/fms060.

Utting, D. & Bewley, S. (2011). Family planning and age-related reproductive risk. *The Obstetrician and Gynaecologist, 13,* 35-41.

Vajpayee, A. & Govila, A. K. (1987). Effect of family structure, family size and crowding on neonatal mortality in Indian villages. *Journal of Tropical Pediatrics, 33*, 61-62. Retrieved from http://tropej. oxfordjournals.org/

VandeSlice, J., Popkin, B., & Briscoe, J. (1994). Drinking-water quality, sanitation, and breast-feeding: their interactive effect on infant health. *Bulletin of the World Health Organisation, 74* (4), 589-601.

Van de Poel, E., O'Donnell, O., Van Doorslaer, E. (2009). What explains the rural-urban gap in infant mortality: household or community characteristics? *Demography, 46* (4), 827-850.

Vandresse, M. (2006). A conceptual model of feto-infant mortality in late and low fertility context. *Document de travail*, *26*, 1-30. Retrieved from http:// citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.476.727 7&rep=rep1&type=pdf

Victora, C., Huttly, S. R., Fuchs, S. C., Olinta, M. T. (1997). The Role of Conceptual Frameworks in Epidemiological Analysis: A hierarchical Approach. *International Journal of Epidemiology, 26* (1), 224-227.

Voss, P. R. (2007). Demography as a Spatial Social Science. *Popul Res Policy Rev, 26*, 457-476. doi: 10.1007/s11113-007-9047-4

Wagura, P., Wasunna, A., Laving, A., Mawalma, D., Nganga, P. (2018). Prevalence and factors associated with preterm birth at Kenyatta National Hospital. *BMC Pregnancy and Childbirth*, *18*, 1-8. Retrieved from https:// doi.org/10.1186/s12884-018-1740-2

Walana, W., Acquah, E. K. S., Abdul-Mumin, A., Naafu, B., Aruk, E., Vicar, K. E., … Ziem, B. J. (2016). Pattern, Causes and Treatment Outcomes of Neonatal Admissions in the Tamale Teaching Hospital. *Clinics in Mother and Child Health, 13* (4), 1-5. doi: 10.4172/2090-7214.1000252

Wang, H., Liddell, C. A., Coates, M. M., Mooney, M. D., Levitz, C. E., Schumacher, A. E., … Murray, C. J. L. (2014). Global, regional, and national levels of neonatal, infant and under-5 mortality during 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*, *384* (9947), 957-979. Retrieved from http://dx.doi.org/10.1016/S0140-6736(14)60497-9

Welaga, P., Moyer, C. A., Aborigo, R., Adongo, P., Williams, J., Hodgson, A., … Engmann, C. (2013). Why Are Babies Dying in the First Month after Birth? A 7-Year Study of Neonatal Mortality in Northern Ghana. *PLoS ONE, 8* (3), 1-8. Retrieved from https://doi.org/10.1371/journal.pone.0058924

Whitworth, A. & Stephenson, R. (2002). Birth spacing, sibling rivalry and child mortality in India. *Social Science & Medicine, 55* (12), 2107-2119.

World Health Organisation (2011). *Improving Equity in Health by Addressing Social Determinants*. World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland: WHO Press. Retrieved from www.who.int.

World Health Organisation (2012). *Born Too Soon: the Global Action of Report on Preterm Birth.* World Health Organization, Geneva. Retrieved from https://www.who.int/pmnch/media/news/2012/201204_borntoosoon-report.pdf

World Health Organisation (2015). *The Transformation Agenda of the World Health Organization Secretariat in the African Region 2015-2020.* WHO, Geneva. Retrieved from https://www.afro.who.int/publications/ transformation-agenda-world-health-organization-secretariat-african-region-2015-2020-0

WHO (2016). *Fact Sheet*. Retrieved from http://www.who.int/mediacentre/ factsheets/fs178/en/

Woldemicael, G. (2000). The effects of water supply and sanitation on childhood mortality in urban Eritrea. *J. Biosoc. Sci., 32*, 207-227.

Yego, F., D'Este, C., Byles J., Nyongisa, P., Williams, J. S. (2014). A case-control study of risk factors for fetal and early neonatal deaths in a tertiary hospital in Kenya. *BMC Pregnancy and Childbirth, 14*, 398-406. doi: 10.1186/s12884-014-0389-8

You, D., Hug, L., Chen, Y., Newby, H., Wardlaw, T. (2014). *Levels and Trends in Child Mortality*. UNICEF, WHO, World Bank Group, UN. Retrieved from https://www.unicef.org/media/files/Levels_and_ Trends_in_Child_Mortality_2014.pdf

You, D., Hug, L., Ejdemyr, S., Beise, J., Idele, P. (2015). *Levels & Trends in Child Mortality*. UNICEF, WHO, World Bank Group, UN. Retrieved from https://www.unicef.org/media/files/IGME_Report_Final2.pdf

Zanini, R. R. B., Moraes A. J., Giugliani E. R., Riboldi J. (2009). Infant mortality trends in the State of Rio Grande do Sul, Brazil, 1994- 2004: a multilevl analysis and community risk factors. Cad. *Saude Publica*, *25* (5), 1035-1045.

Zanini, R. R., de Moraes, A. B., Giugliano, E. R. J., Riboldi, J. (2011). Contextual determinants of neonatal mortality using two analysis methods, Rio du Grande du Sul, Brazil. *Rev Saudi Publica, 45* (1), 1-10. Retrieved from www.scielo.br/rsp

APPENDICES

APPENDIX I

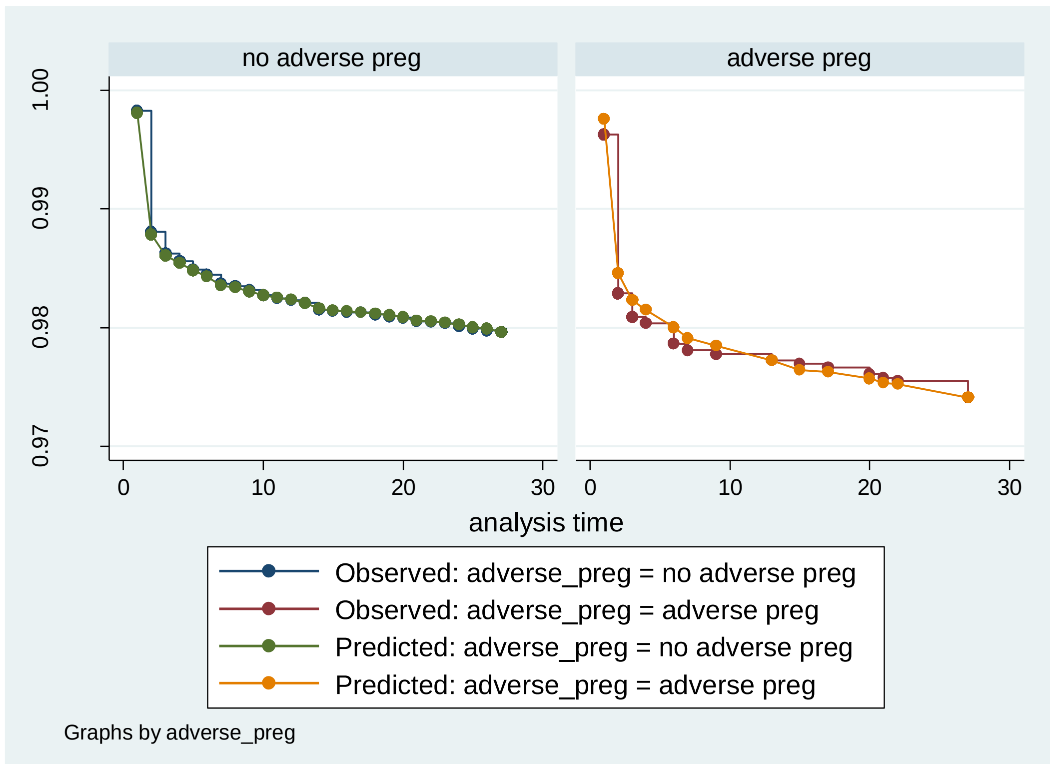
Proportional hazards assumption test for individual, household and community level variables

Variable	Chi-squared value	Global p-value
Sex	1.44	0.230
Birth order	0.98	0.322
Educational level	0.76	0.384
Tetanus toxoid	0.10	0.753
Gravidity	2.89	0.089
Maternal age at delivery	5.50	0.019*
Previous adverse pregnancies	0.02	0.879
Place of delivery	20.35	<0.001*
Gestational age	0.36	0.550
Household wealth	0.00	0.994
Crowding	0.00	0.986
Ethnic heterogeneity	0.00	0.980
Average distance to the nearest health facility	0.30	0.584
Average travel time to water source	0.01	0.908
Poverty	0.23	0.631
Sanitation	0.26	0.611
Water safety	0.02	0.890
Community education	0.19	0.660

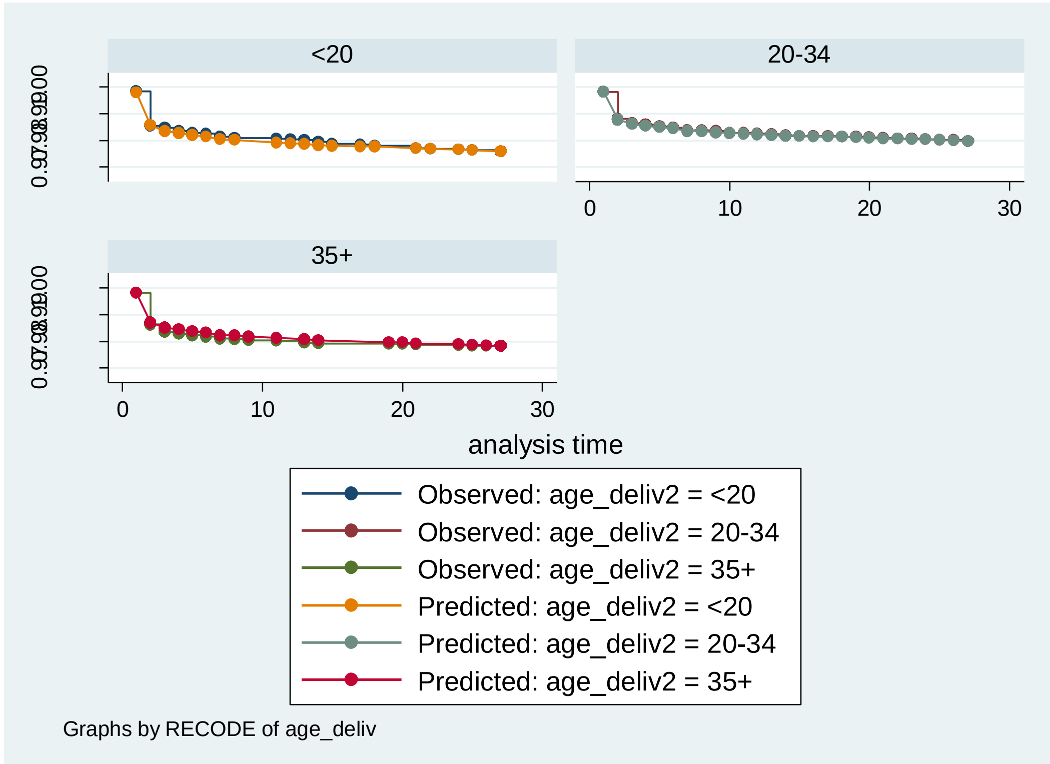
*Statistically significant and therefore violates the proportional hazards assumption

Source: Adjei (2019)

Proportional hazards assumption graphs comparing Kaplan-Meier observed survival with Cox predicted curves



Source: Adjei (2019)



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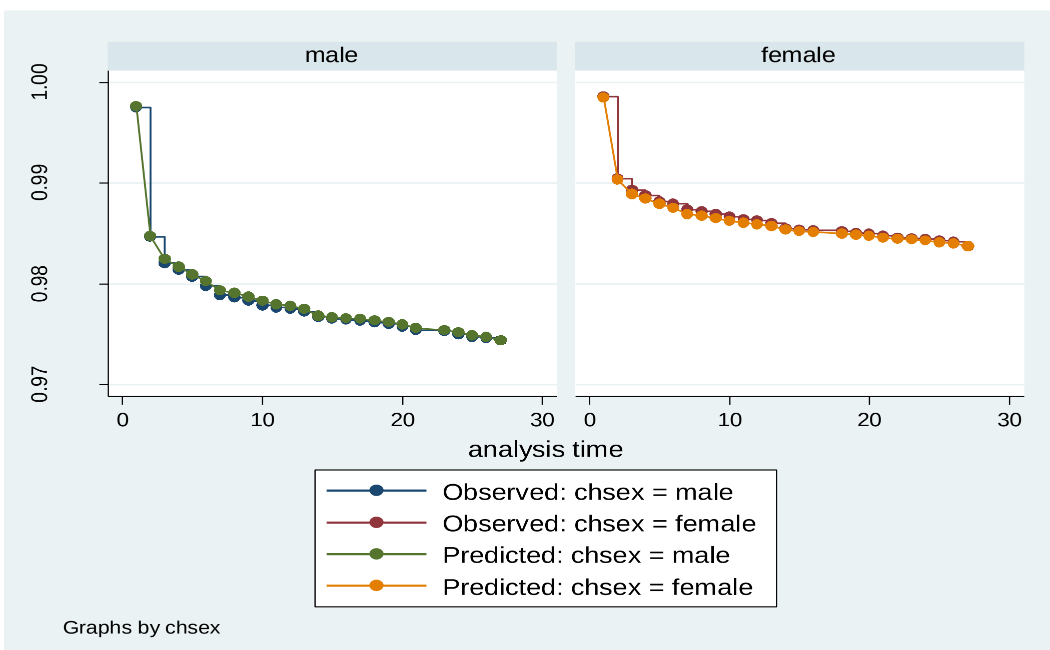

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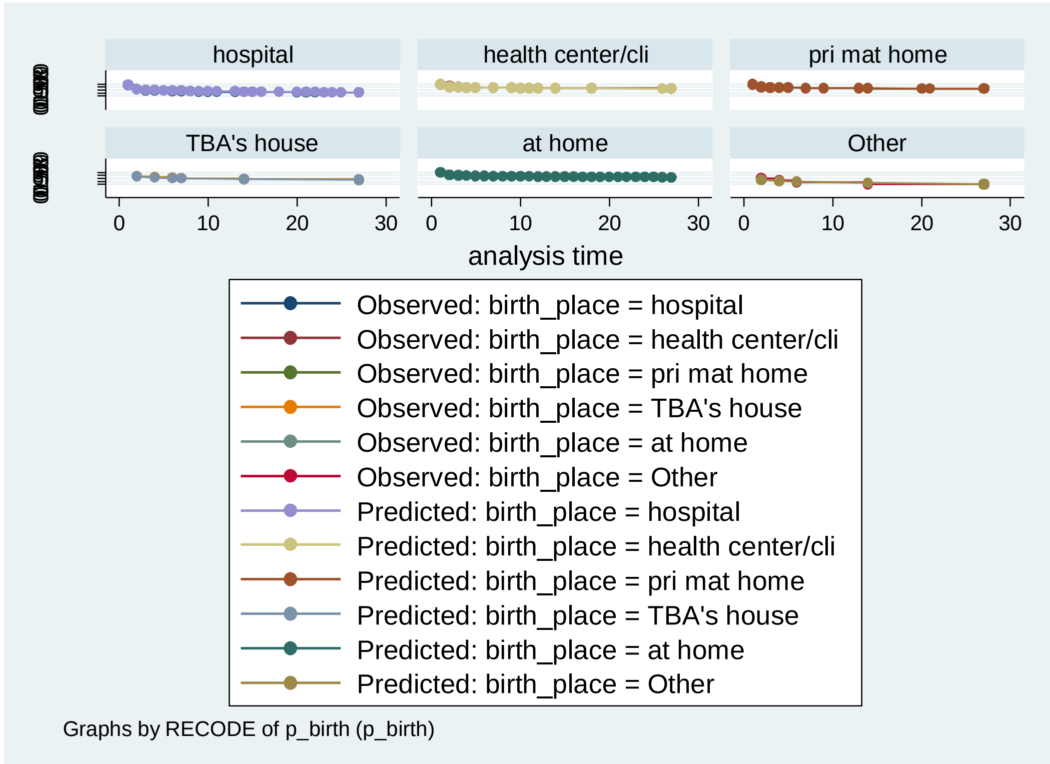

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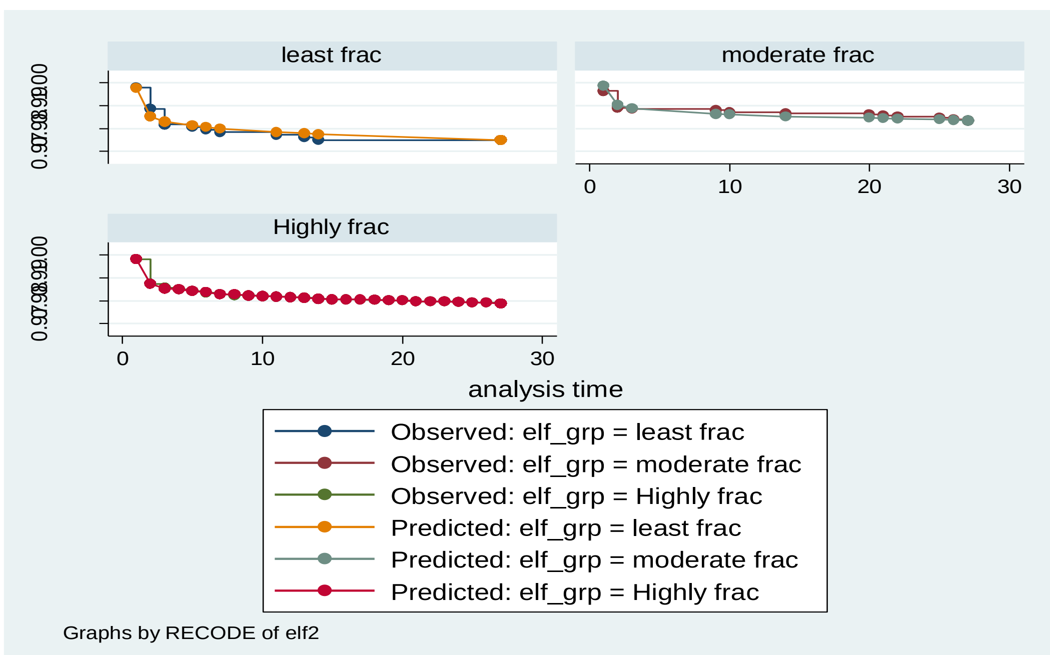

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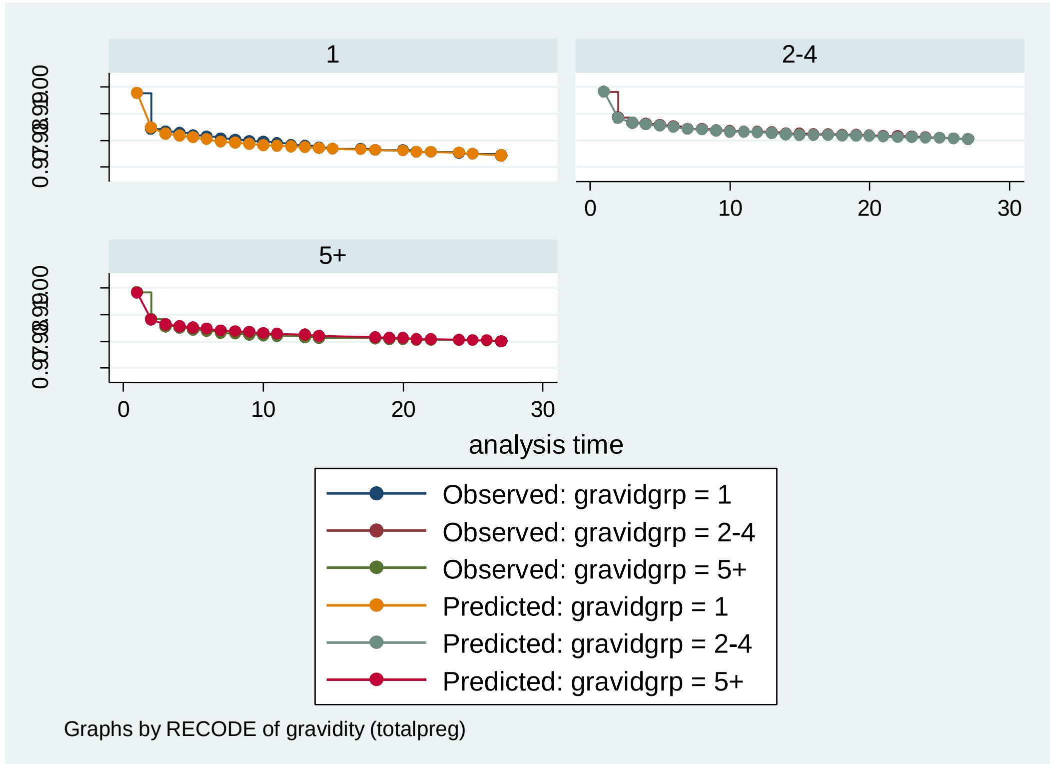

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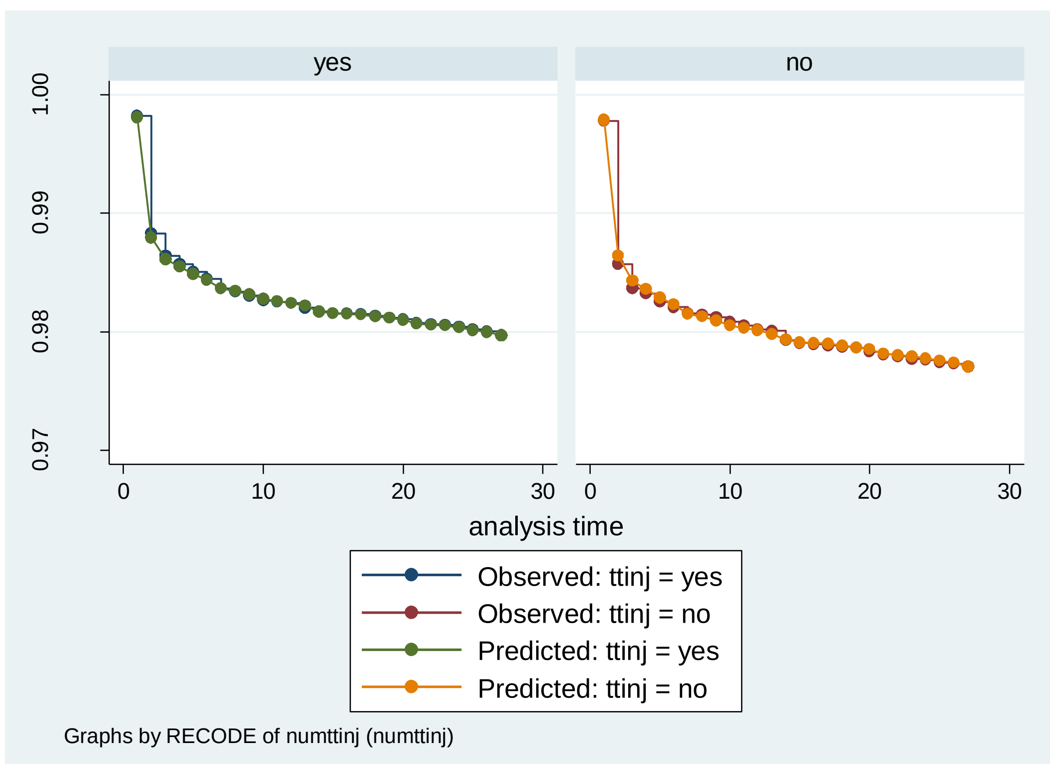

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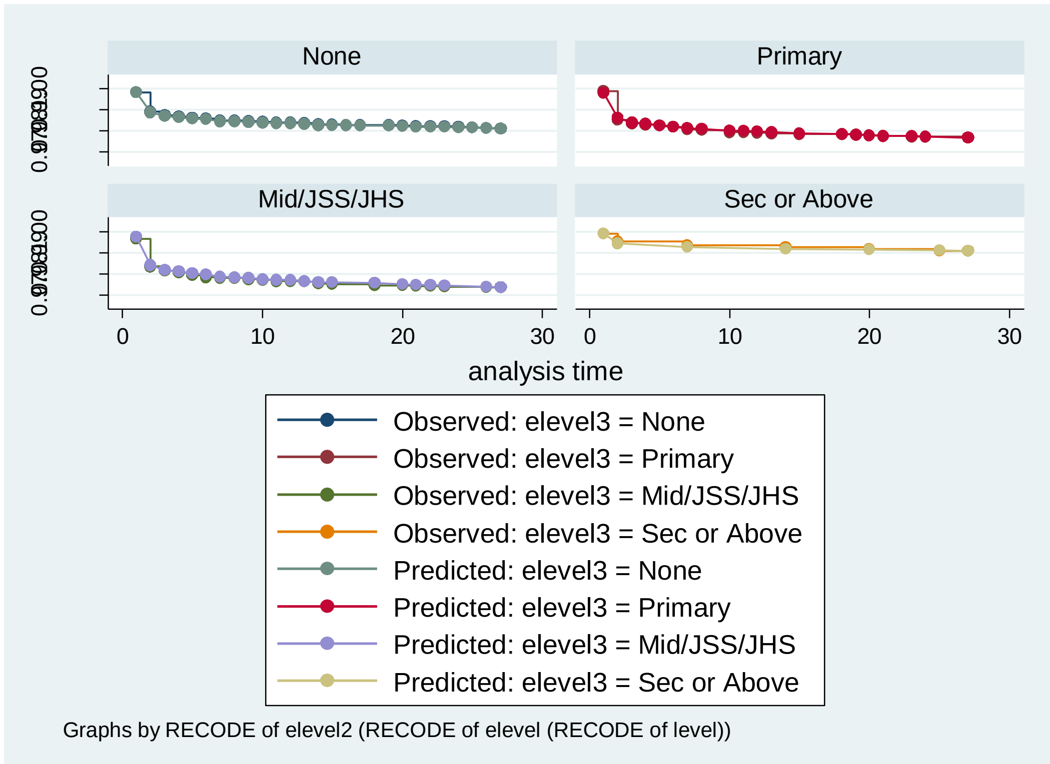

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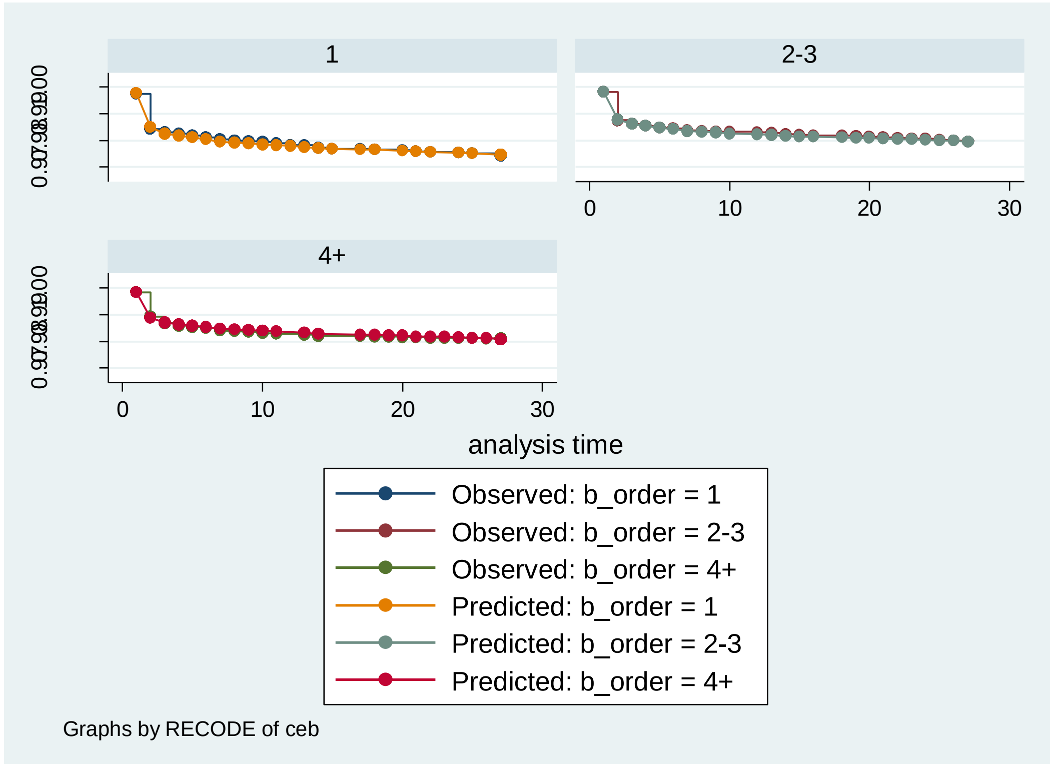

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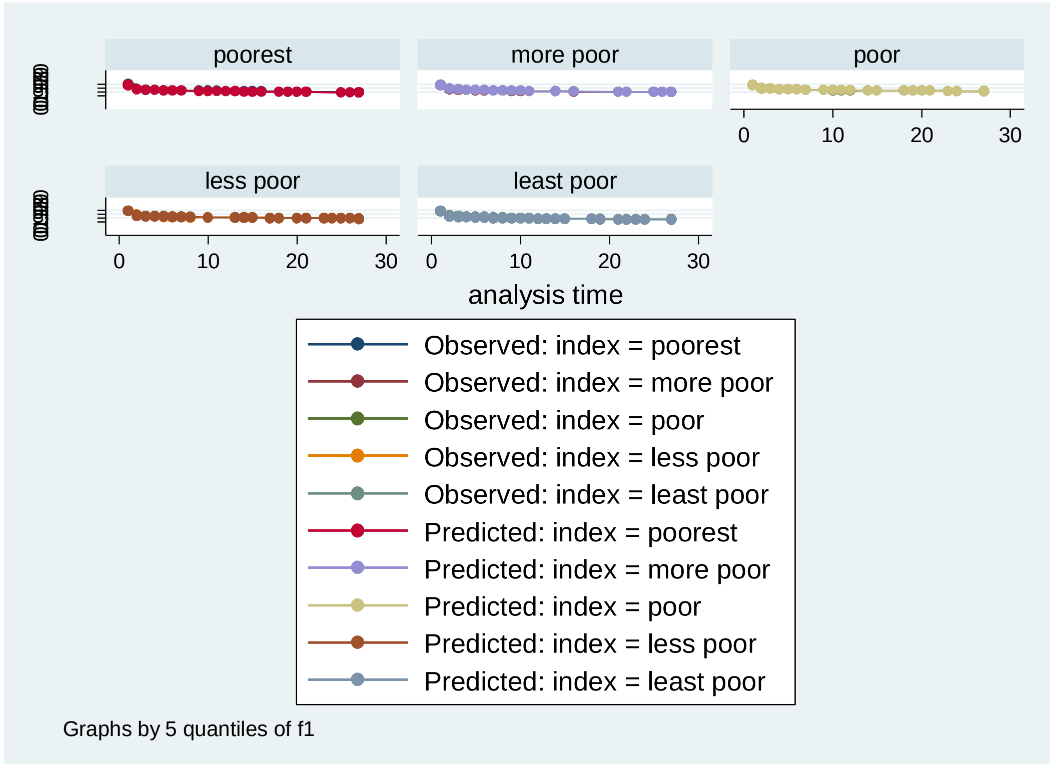

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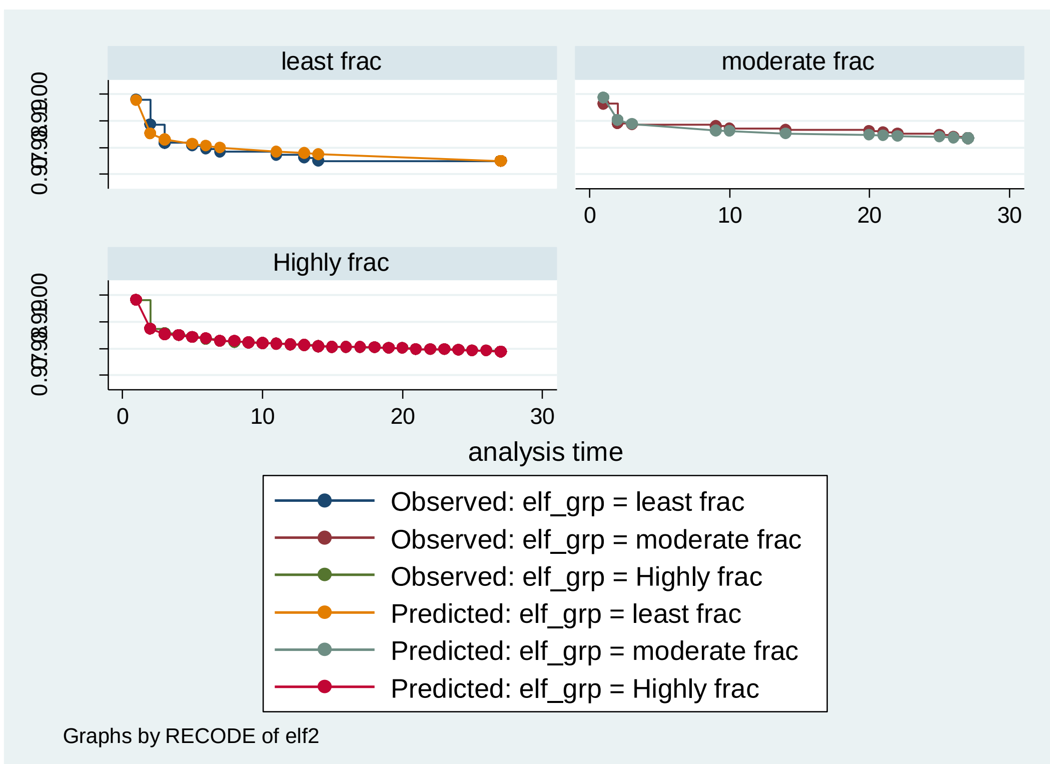

Source: Adjei (2019)

Appendix II

Variable	Standard error for Model IV	Robust standard error
Sex		
Male	-	-
Female	0.092	0.055
Birth order		
1	-	-
2-3	0.317	0.376
≥4	0.344	0.324
Educational level		
None	-	-
Primary	0.118	0.141
Middle/JHS/JSS	0.122	0.161
Secondary or above	0.369	0.137
Tetanus toxoid		
Yes	-	-
No	0.101	0.136
Gravidity		
1	-	-
2-4	0.323	0.213
≥ 5	0.373	0.270
Maternal age at delivery		
<20	-	-
20-34	0.153	0.165
35+	0.206	0.258
Previous adverse pregnancies		
Yes	0.141	0.194
No	-	-
Place of delivery		
Hospital	-	-
Health Centre/Clinic	0.209	0.084
Private maternity home	0.209	0.094

TBA's house	0.390	0.272
At home	0.110	0.064
Other	0.510	0.502
Gestational age	0.009	0.008
Household wealth		
Poorest	-	-
Poorer	0.144	0.121
Third	0.150	0.104
Second	0.141	0.126
Wealthiest	0.137	0.142
Crowding	0.034	0.031
Ethnic heterogeneity		
Least fractionalised	-	-
Moderately fractionalised	0.350	0.319
Highly fractionalised	0.300	0.309
Distance to nearest health facility	0.062	0.060
Travel time to water source	0.005	0.006
Poverty	0.022	0.022
Sanitation	0.004	0.004
Water safety	0.004	0.004
Community education	0.058	0.059

Source: Adjei (2019)