TITLE: RISK FACTORS ASSOCIATED WITH UNDER-FIVE MORTALITY IN NORTHERN GHANA BETWEEN 2007 AND 2012.

BY

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A RESEARCH REPORT SUBMITTED TO THE SCHOOL OF PUBLIC HEALTH, UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN EPIDEMIOLOGY IN THE FIELD OF BIOSTATISTICS

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DECLARATION

I, Samuel Tomilola Oladokun declare that this research report is my own work. It is being submitted for the degree of Master of Science in Epidemiology in the field of Biostatistics in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

Signature: 

6th Day of October, 2020

DEDICATION

This work is dedicated to my late wife Adelaide Mahama, my children (Divine, Favour and Precious), my siblings (Emmanuel and Jorom), my dad, Philip Oladokun and late mother, Cecilia Oladokun. Through thick and thin, provided all the support to make me achieve this level of education.

ABSTRACT

Introduction: Under-five mortality is still a critical issue globally, especially in Sub-Saharan Africa. The disparities between low- and high-income countries in respect to mortality in children continue to be high and persistent. According to WHO, under-five mortality rate was 73.1 per 1000 live births in low income countries compared to 5.3 per 1000 live births in high-income countries in 2016 – almost 14 times higher on average. The African region, being home to many low-income countries, is particularly affected. In fact, of all the WHO regions, the WHO African Region has the highest under-five mortality rate of 76.5 per 1000 live births.

Objectives: This study assessed the risk factors associated with under-five deaths, described the leading causes of under-five deaths and examined the spatial variations of under-five deaths in northern Ghana between 2007 and 2012.

Methodology: Data for this study came from the Navrongo Health and Demographic Surveillance System (NDSS) in the upper east region of Northern Ghana. Children born between 1st January 2007 and 31st December 2012 and resident in the HDSS area were included in the analyses. The children were followed up from first date of registration into the surveillance area till they were five years of age or censored depending on which comes first. Survival estimates were computed using Kaplan-Meier survival technique. Cox proportional hazards regression models were used to assess the risk factors associated with under-five deaths. Verbal autopsy data were used to ascertain causes of under-five deaths using InterVA4. Choropleth maps were used to depict the geographical distribution of under-five deaths across the study area.

Findings: A total of 20,651 children were included in the analyses. Over the follow-up period, 1,010 under-five deaths were recorded with 51,783 person years of observation. Overall, under-five mortality rate was 19.5 per 1000-person years of observation (PYO). The risk factors which

were significantly associated with under-five deaths were sex of child, marital status of the mother, maternal age, socio-economic status (SES), and birth place. Children born to mothers who were aged 20-34 years had 19% reduced risk of dying before age five compared to children born to mothers who were less than 20 years old (HR=0.81, p=0.034, 95% CI: 0.67, 0.98). Children from the richest households were less likely to die before their fifth birthday relative to those from the poorest households, after controlling for other covariates (HR=0.72, p=0.028, 95% CI: 0.54, 0.96). Children born at home had an increased risk of dying compared to those born at the health facility (HR=1.29, p<0.001, 95% CI: 1.12, 1.48) after adjusting for other covariates. The risk factors that were found to be associated with under-five deaths due to Non-Communicable Diseases (NCDs) were marital status, SES, birth place and mother's level of education. On causes of death, 30% of all under-five deaths were due to malaria and 18% were attributed to Acute Respiratory Infections (ARI), including Pneumonia. The three leading causes of neonatal deaths in the study area were neonatal pneumonia (29%), prematurity (25%) and birth asphyxia (23%). Most of the neonatal deaths (71%) occurred in the early neonatal period of 0 to 6 days.

Conclusion: Under-five mortality rates in the study area remain relatively high with marginal differences across clusters. Maternal age of less than 20 years, low socio-economic status of mother, being a male child, being a single mother, children born to mothers with no formal education and children delivered at home were at significantly increased risk of under-five deaths in the study area. Malaria and pneumonia are the leading causes of under-five deaths in the study area. To achieve the sustainable development target of reducing child mortality by 2030, it is important to identify the major risk factors which affect child mortality, as well as the major causes of child deaths at the district or local level in order to develop targeted interventions.

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LIST OF ABBREVIATIONS

aHR	Adjusted Hazard Ratio
AIDS	Acquired Immune Deficiency Syndrome
UMMP	Under-five Morbidity and Mortality Project
UMR	Under-five Mortality Rate
CD	Communicable Disease
COD	Causes of Death
DSA	Demographic Surveillance Area
HDSS	Health and Demographic Surveillance System
HIV	Human Immunodeficiency Virus
ICD 10	International Classification of Diseases version 10
NHDSS	Navrongo Health and Demographic Surveillance System
INDEPTH	International Network for Continuous Demographic Evaluation of Populations and Their impact on Health in Developing Countries
MDGs	Millennium Development Goals
NCD	Non-Communicable Disease
PCA	Principal Component Analysis
PYO	Person's Year Observed
SES	Socioeconomic Status
uaHR	Unadjusted Hazard Ratio
VA	Verbal Autopsy
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Background of the study

Under-five mortality is still a critical issue globally, especially in Sub Sahara Africa. The disparities between low- and high-income countries in respect of mortality in children continue to be high and persistent (1). According to the 2016 WHO statistics, the death rate for under-five was 73.1 deaths out of every 1000 live births in low income countries compared to 5.3 deaths out of every 1000 live births for the high income nations – almost 14 times higher on average (1). The African region being home to many low-income countries is thus particularly affected. In fact, of all the WHO regions, the WHO African Region has the highest threat of a child dying prior to reaching the age of five years (76.5 per 1000 live births) (1). These statistics are especially worrying given the fact that globally, under-five mortality rate has decreased to 39 deaths out of every 1000 live births in 2017 from 93 deaths out of every 1000 live births in 1990, representing a drop of 58% (1), whereas in the African regions it does not decrease. About 15 000 less children died daily in 2017 compared to 1990 (2) but the situation seems to remain the same in Sub-Saharan low-income countries including Ghana. It is therefore imperative to determine the drivers of risk regarding mortality of children under five years in Ghana in order to understand the issues contributing to the high under-five mortality death rates in Sub Sahara Africa and address them. That is why, this study will investigate factors driving the risk of deaths of children under five years of age in Northern Ghana from 2007-2012 based on data from the Navrongo Health Research Centre in Ghana.

The Millennium Development Goals (MDGs) were introduced in September 2000 to assist countries to improve on the quality of life of their populations. The 8 MDGs which were set to be

achieved in 2015 dealt with issues such as poverty, education, gender equality, mental health, environmental sustainability, development, malaria, HIV/AIDS, and the reduction of child mortality which is the fourth goal (3) . MDG4 mainly focused on shrinking mortality of children by two thirds globally between 1990 – 2015 (4). However, the MDGs which were based on the actions and targets as captured in the Millennium Declaration adopted by 189 countries and assented to by 147 heads of states and governments at the September 2000 UN Millennium Summit (5) were not achieved in many countries and this was especially true for the MDG4 in Ghana. Thus, in order to meet the targets that were not met with the MDGs, UN Member States adopted a new programme meant to deliver sustainable development by 2030. This programme, dubbed 'Sustainable Development Goals' (SDGs), encompasses seventeen goals with wide ranging targets numbering 169, is expected to be operationalised in all countries by all stakeholders (6). Key among those targets is the expected reduction in mortality of children (both newly born and children below the age of five). It is targeted that neonatal mortality in every country would drop to twelve deaths out of every thousand live births and mortality of children below the age of five would be brought down to twenty-five deaths out of every thousand live births by 2030 (1).

Most causes of death among children in developing countries are preventable (7). These include: pneumonia, acute respiratory infections and other risk factors such as malnutrition, low birth weight, unsafe drinking water and food, overcrowded conditions, not breastfeeding children and poor hygiene practices (2). Child mortality in the Kassena-Nankana district is said to be mainly caused by malaria, diarrhoea, pneumonia, and anaemia (8). Cost effective preventive measures such as: adequate nutrition, vaccination, safe water and food, exclusive breastfeeding, adequate sanitation and hygiene and the reduction of household air pollution can be used to reduce risk of dying for children under the age of five years (2).

In Northern Ghana, studies have shown that single and widowed women from the Mole-Dagbani ethnic community, traditionalist women and Islamic women experienced higher infant and child mortality rates (9). Moreover, the age of the mother at birth, her level of education, and the socioeconomic status of her household were significantly related to child mortality (8).

From as high as 128 recorded deaths out of every 1000 live births in 1990, the mortality of children below the age of 5 in Ghana dropped to 62 deaths in 2015, a 52% reduction (10). The steady decrease was attributed to the implementation of the child strategy interventions and policy on child health (11). However, regardless of these decreasing rates, much remains to be done so as to meet the 2030 SDGs targets especially in the northern part of Ghana. For this reason, there is a need for researchers to effectively determine the causes of deaths of under-five children so as to come up with effective interventions that would help reduce these deaths. Verbal autopsy (VA) is progressively being utilised to account for patterns of deaths in circumstances when such deaths do not take place in a hospital or when they take place in health facilities whose diagnostic competencies are limited (12). This method of determining causes of death is appropriate for most parts of rural Northern Ghana where many children die outside of the hospitals and factors related to their deaths are not recorded, and where data from the hospitals do not provide enough details to effectively assign the causes of under-five deaths.

However, there are concerns raised regarding the reliability of information on symptoms gathered from families as regards to re-call of the events. In addition, the realism of depending on physicians to examine anonymous questionnaires on symptoms to ascertain the cause of death is also an issue of concern for researchers (12) .

1.2 LITERATURE REVIEW

The reduction of child mortality is determined by a number of factors including healthcare services that cover the antenatal, intra-natal and post-natal periods. In fact, the period of neonatal (the beginning 28 days of life) is the period in which a child's risk of dying is greatest. So, it is vital to improve the quality of antenatal care, intra-natal care, as well as postnatal care for newborns and their mothers to avert deaths (13) .

Mosley and Chen (1984) suggest that when developing strategies to reduce child mortality, a number of mechanisms and determinants of under-five mortality need to be considered. Biological mechanisms and a number of proximate determinants essentially serve as the channels through which social and economic drivers of mortality in children influence such mortalities (14). The proposed study is based on the work of Mosley and Chen (1984) in formulating the framework for the identification of the proximate determinants that exert direct influence on mortality and morbidity risk in children. The proximate determinants through which the social and economic factors work are health-seeking and nutritional culture, maternal factors and the environment (15). In this study, we focus on maternal factors and the biological environment. The following section discusses the social and economic factors that are critical to the survival or otherwise of children and which will be the subject of analysis in the present study.

1.2.1 The Social and Economic Determinants of Child Mortality

Developing countries account for more under five deaths than high income countries. In fact, the lack of strong health systems in low income countries contributes greatly to under-five mortality (13). A country’s well-being is determined by its social and economic development. These economic and social growth are also dependent on accessibility to good and quality health care for

all citizens as well as healthy living conditions. The health of people is therefore affected by socio-economic factors because understaffed or underequipped healthcare facilities cannot provide effective healthcare to populations (16). Also, the lack of cash to settle important care services (16) may result in the death of the woman and the baby.

In terms of social factors, at the individual level for instance, the woman, depending on her autonomy, personal wealth or income, occupation, and the level of her education, takes decisions regarding her health (16). In the same vein, a community's social patterns influence the social constraints (16). For example, senior members of the family like mothers-in-law continue to have considerable say on decisions regarding pregnancy, child birth and child care in many traditional areas (16). A typical scenario of a cultural constraint would be that elders may not allow their wives in many traditional areas to have a caesarean section even when it is imperative (16). Likewise, some husbands in more traditional settings may forbid the vaccination of their children and in case the child catches a critical disease for which he/she was supposed to be vaccinated (16).

In line with the work of Buwembo (2010) and in tandem with the framework developed by Mosley and Chen (1984), the identified socioeconomic factors to be examined in this study are education of the mother, mother's marital status, the gender of the child, the parity, the season of birth, multiple births, religion, place of delivery (health facility or home) and wealth index or quintile.

1.2.2 Educational Level of the Mother

Mosley and Chen (1984) posit that the level of education of the mother is a critical factor that influences the survival or otherwise of the child. This, according to the authors, is so because the level of education attained by the mother informs the choices she makes and actions on issues of

hygiene, disease treatment, preventive care, nutrition and contraception. Hobcraft et al (1984) found the level of education attained by the mother to be relevant in the determination of the survival of children. They argued further that no threshold exists for the educational level attained by the mother at which point the benefits of child survival could be obtained. Indeed, whatever the level of education of the mother, survival benefits are obtained once there is some form of education.

For sub-Saharan African countries however, a number of studies have indicated that the child-survival benefit of the mother's educational level is minimal compared to the Latin American and Asian countries (15). Hobcraft (1993) attributes the weak association between the educational level of the mother and the survival of children across sub-Saharan Africa to the rather weak infrastructure in the region which does not allow mothers who are educated to translate such training into avenues for extracting health benefit.

In a related study of a number of African countries, Madise et al (1999) found that mothers whose educational level was secondary or higher manage their children health better. Mosley and Chen (1984) posit that the level of education of the father can have an impact on the child's health, particularly in choosing the kind of food to consume. The authors add that the impact of the level of education of the father on the child's survival is more pronounced if the father marries a woman who has very little education.

1.2.3 The Place of Residence of the Mother

Mother's residential location has an effect on the nutritional and survival situation of children, particularly in developing countries (15). Other studies have supported this assertion (20–22). Mothers dwelling in the cities or urban communities are able to access improved infrastructure

and health services compared to their counterparts in the rural communities. As established in the work of Machado and Hill (2005), children whose mothers live in the urban communities are most likely to survive the neonatal period. The authors observed that better infrastructure in urban communities helps to promote good hygiene practices (23).

Urbanization has been on a rise globally and this led to a jump in the urban population worldwide surpassing the 54% mark (24). It has therefore been predicted that globally majority of the world's population will be found in urban areas. This will be much more experienced in sub-Saharan Africa (25).

The 2013-2015 data from the Global Health Observatory emphasizes that most of child mortalities are recorded in urban dwellings of low- and middle-income countries and the difference in these deaths varied per country. It was found that there was a difference of at least 50 deaths per 1000 live births between rural and urban dwellings. Childhood mortality was found to be higher in urban slum areas as compared to rural and non-slum urban areas as revealed by a study from Kenya. (26).

A study in Bangladesh revealed a relationship between place of residence and under-5 mortality (27). It further sowed that child mortalities were significantly higher for rural mothers compared to urban. There was a higher rate of survival in children brought up in urban areas as compared to rural settings (66%) (27). Stephenson et al. (2002) and Stephenson et al. (2019) opined that access to health services and economic status were largely depended on when dealing with the levels of under-5 mortality in rural and urban areas. Socio-economic variations play a signification role in under-5 mortality. It is therefore important to check socio-economic, behavioral and demographic factors that can help appreciate the differences when assessing the rural-urban impact of child

mortality. Variations in the socio-economic levels play a critical role in under-five deaths. For one to effectively analyze the rural-urban impacts of child deaths, it is important to check the socio-economic, behavioral and demographic factors that can help to explain the difference (29).

1.2.4. *Mother's Labour Market Status*

The employment status of the mother is another important factor that can have a dual effect. Hobcraft e tal (1984) contend that a working mother may have challenges feeding and taking proper care of the child and that can affect the probability of the child's survival. On the other hand, the extra income earned by the mother can help enhance the child's chances of survival due to good living and the ability to afford better health care. In the work of Kishor and Parasuraman (1998), it was established that when mothers work, the chances of the survival of their children reduces, especially when the mothers' work place is far from home.

1.2.5 Biological and Maternal Determinants of Survival of children

For the maternal and biological determinants of survival of children, Mosley and Chen (1984) outlined factors that include age of the mother, birth order and birth interval as the main drivers of the survival or otherwise of children. Other studies have linked these factors to the survival of children (31–33).

1.2.6 Birth Order

According to Buwembo (2010), various studies have shown that strong association exist between increased death and children who are first to be given birth to by their mothers (15). This assertion is supported by the work of Hobcraft et al (1985), who established high risk of neonatal death for first-born children.

1.2.7 The birth Interval

Short intervals of births are perceived to heighten the risk of death in children (15). Boerma and Bicego (1992) established the avenues by which intervals of birth can affect the survival of the child. These avenues, according to the authors, are mechanisms relating to prenatal and postnatal care. In respect of prenatal mechanisms, the argument is that mothers who get pregnant at short intervals (successive pregnancies) have limited time to recover the nutritional requirements after their previous delivery and this can affect the growth of the fetus (15). As for postnatal mechanisms, authors enumerate factors such as mother's poor nutritional culture which can impair childcare efforts as lactation is badly affected. Competition between siblings can also affect child survival. A study by Boerma and Bicego (1992) found that postnatal are less significant when compared to prenatal factors.

1.2.8 Mother's Age

Authors such as Machado and Hill (2005), Rutstein (2000), and Hobcraft et al (1985) have established the relationship between the survival of children and the mother's age. Ribeiro *et al* (2014) posit that a mother's age pose an enormous upside gestational and mortality risk. The mother and child are at enormous risk for pregnancies that occur at adolescent age or ages greater than 45. According to the WHO (2014), although the number of births among the adolescents has trended downwards since 1990, the high fertility level between the ages of 11 and 19 account for 11 percent of total births.

Hobcraft et al (1985) established that children who are born by mothers of teenage age had high risk of death. On the other hand, Mahmood (2002) found that there is substantial risk of neonatal and postnatal death among children who are born by mothers between the ages of 30 and 39. Fall

et al (2015) conducted a study that evaluated factors such as low child birth weight and associated risk, preterm delivery and inability to finish school. The authors engaged participants drawn from Philippines, Guatemala, Brazil, South Africa and India. They documented increasing mother's age to pose an upside risk to preterm delivery with severity in countries classified as low and middle income. Dube et al (2012) found young mothers in Zimbabwe to have higher risk (33% more) of recording infant mortality than their older mother counterparts. First time deliveries by adolescent mothers is said to carry significant risk of death of the children although some authors have also found middle-aged mothers of about 27 years and above making their first delivery to have children with high risk of anemia, diarrhea and stunted growth (Finlay et al, 2011). In Nigeria, under five mortality was found to be prevalent among mothers below the age of 20 (40)

1.2.9 Sex of the child

Studies have established that differences exist in child mortality by sex of the child. Neonatal mortalities are high among male children when compared to female children but the opposite is true in postnatal deaths (15). Empirical works by Arokiasamy (2004), Chen et al (1981) Bhuiya and Streatfield (1991) also support this position. The United Nation, (2011) reckons that new female babies naturally have a higher survival chance than their male counterparts although in countries like China and India the male children have lower rate of mortality in the under 5 category. This is corroborated by other findings in India, particularly central and northern regions, that mortality in female babies exceeded that of their male counterparts (44) In Sub-Saharan Africa, it is the male babies below the age of 5 who are highly susceptible to deaths (45) . A case in point can be said of Nigeria where males are more likely to die before their 5^{th} birthday (45).

1.2.10 Wealth Index

Victora *et al* (2003) posit that a significant dichotomy between rich and poor nations regarding mortality of children exist. Within country differences are also observed between the rich and the poor regarding child mortality. There is greater susceptibility of poor children to diseases than their counterparts from affluent homes. Economic disparities tend to benefit the rich in respect of mortality in infants (47). A study in Tanzania's rural south revealed that while poor parents were unlikely to seek proper healthcare for their children, rich parents offered their children good healthcare services opportunities (48) Similar findings were made regarding children from poor homes relative to their peers from rich families in 47 courtiers (49). Barros *et al* (2010) with reference to data released from 1990 found that children from poor homes to be prone to pathogens that induce sickness and the lack of proper healthcare for these children increase the chances of mortality below the age of 5.

1.3 Cause specific and all cause of under-5 Mortality.

Across the world, 6 out of every 10 deaths is attributable to non-communicable conditions, with 3 and 1 attributable to communicable and injuries respectively (1). In 2015, as many as 2 million under five deaths occurred and preterm related issues dominated the causes of these deaths particularly in South Asia. Meanwhile, the causes of these deaths in Sub-Saharan Africa was dominated by pneumonia. For countries with high under five mortality, preterm related issues were the main causes while countries with low under five mortality rate had congenital issues as the main cause (51). In 2015, Wang *et al* (2016) noted diarrhea as the major cause of mortality in children.

1.4 Verbal Autopsy

Lately there has been a steady increase in the use of VA in monitoring causes of death. India, Brazil, and Sri Lanka are among developing countries that have used VA in gathering data officially. It has also been used in Mozambique, Tanzania and Zambia to develop systems for registration of national sample (12).

For low-resource settings, VA becomes a probable alternative for collection of data to observe improvement in respect of their development strategies, so long as this option shows to be routinely applicable, reliable and realistic (12). The use of VA may be a realistic and reliable option for Northern Ghana for two reasons: Firstly, many children die out of the hospital setting. Secondly, even when children die at the hospitals, sometimes there are not enough details about the causes of death. For instance, at a hospital, a parent may not mention feeding pattern of the child before his/her death and that is a crucial element for health practitioners and statisticians to understand the cause of death of the child. Thus, VA enables health practitioners and statisticians to interview members of the family to check if they can remember any characteristics, symptoms and signs of the deceased family member as well as preceding events to that person's demise, and the decedent's healthcare experience. Also, the increased usage of VA which is applied routinely in the health insurance systems of nations has the capacity to significantly advance the accessibility of trustworthy and important data on what causes death to enable the formulation of programmes for disease control across the globe (12).

1.5 Problem Statement

Despite the measures taken by the Ghanaian Government such as the Community-based Health and Planning services (CHPS), and other programmes tailored at training health professionals by

NGOs and alike, under-5 mortality levels still remains high in the country (Ghana) at 60 deaths out of every 1000 births recorded (53). Furthermore, differences in the rates of death of children under five years still exist from one region to another in Ghana, with the upper east region recording a relatively higher rate of 72 deaths per 1000 live births (53). These therefore indicate that a lot of efforts must go into achieving the SDG3 target 2 which require deaths for those under-five years of age to be at most 25 per thousand live births. This high risk observed in Ghana is of concern and, through verbal autopsy, requires an in-depth understanding of the causes and risk factors associated with these deaths (54).

1.6 Justification of the Study

Under-5 deaths is still a significant public health concern as most children are still unable to live beyond their 5th Birthday due to diseases which can be treated and prevented with interventions that are proven and effective in terms of cost (55). Despite the numerous interventions employed, Ghana is experiencing challenges in attaining the targeted SDG levels of less than 25 death per 1000 live births by 2030 (11). Several strategies are therefore required to achieve this target. Thus, there is the need to evaluate the cause of under-5 deaths through the analysis of the trends over time and the identification of possible factors that contribute to child deaths in order to identify new interventions and improve already existing interventions.

The current study intends to assess the demographic and socioeconomic factors that affect under-5 the deaths as well as establish the causes of these deaths in a rural setting in North of Ghana. The outcomes from this research will contribute to the existing studies on mortalities of children under-5 in a rural and poor settings. This may help decision-makers and other stakeholders to identify

relevant interventions which when implemented well can reduce the rate of under-5 mortalities interventions in Ghana as well as in other nations with similar settings.

1.7 Study question

What are the causes and risk factors associated with under-five mortality in Northern Ghana?

1.8 Aim

The study determined the causes and risk factors associated with under-five mortality in northern Ghana between 2007 and 2012.

1.8.1 Specific objectives

1. To describe the socio-demographic characteristics of under-five children in the Kassena Nankana districts between 2007 and 2012.
2. To describe the leading causes of death among under-five children in northern Ghana between 2007 and 2012.
3. To examine the spatial variations of under-five deaths in the Kassena Nankana districts between 2007 and 2012.
4. To determine the risk factors associated with under-five deaths in northern Ghana between 2007 and 2012

Conceptual Framework: Risk factors associated with Under-five Mortality

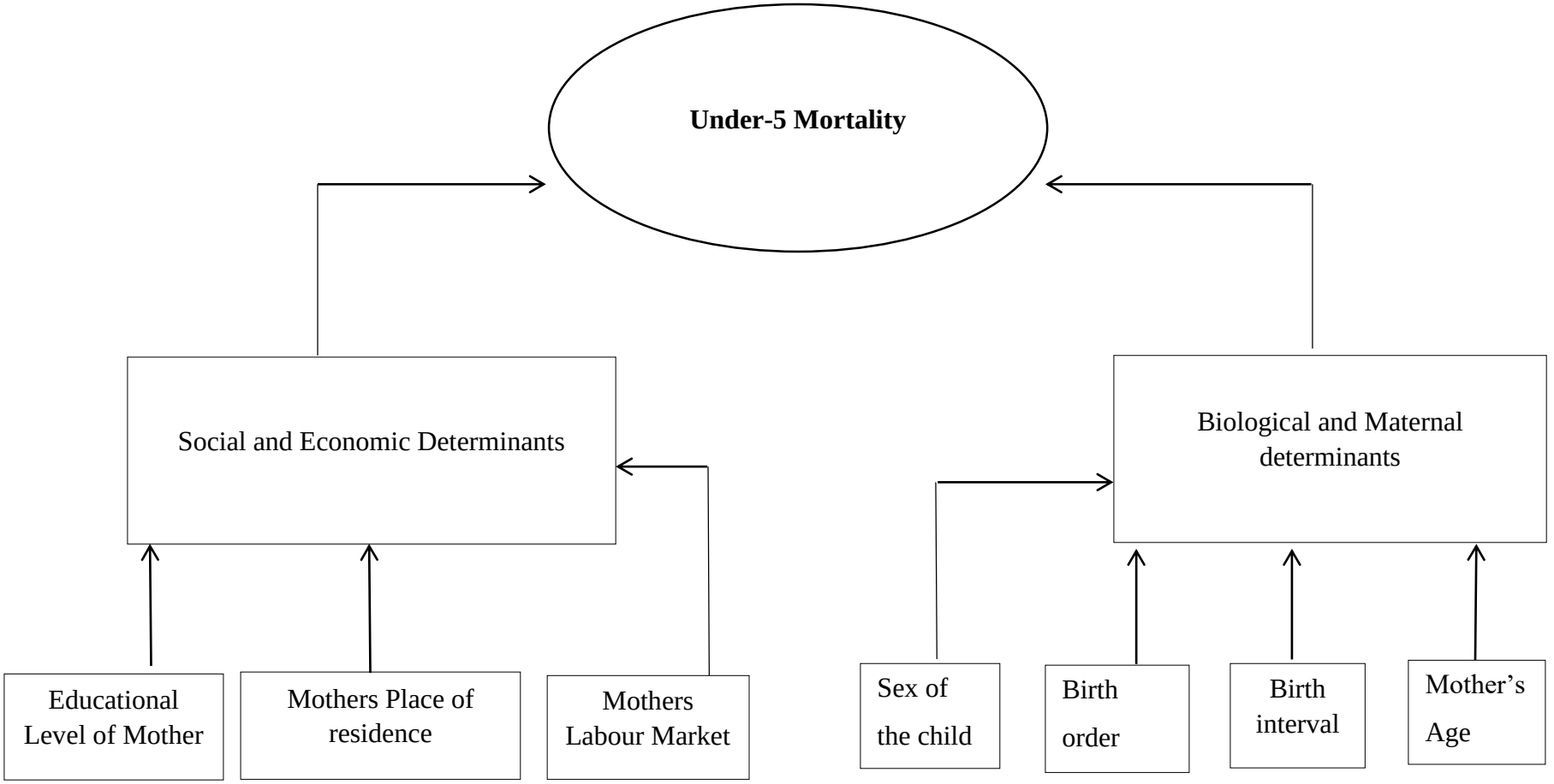


Fig 1: Conceptual framework on Risk factors affecting under-five mortality (Adopted from (56))

CHAPTER 2: METHODOLOGY

2.1 Study area description

This study sourced data from the Navrongo Health and Demographic Surveillance System (NHDSS). The NHDSS is managed at the Navrongo Health Research Center (NHRC). The center is located in the Kassena Nankana Municipality of the Upper East Region of Ghana. (Figure1). NHRC has a designated mandate of conducting health research on contemporary and prevailing issue in the 5 administrative regions of Ghana. It is one of the three research centers of the Ghana health Service. The NHDSS is operationalized in 2 districts that is the Kassena Nankana West and the Kassena Nankana East (figure1) and this geographically located between lat 10.30' and 11.10' N and Lon. 1.1', covering a land area of 1675 km^2. Socio-demographic and health indicators of the study area is routinely captured and updated on a quarterly (8).

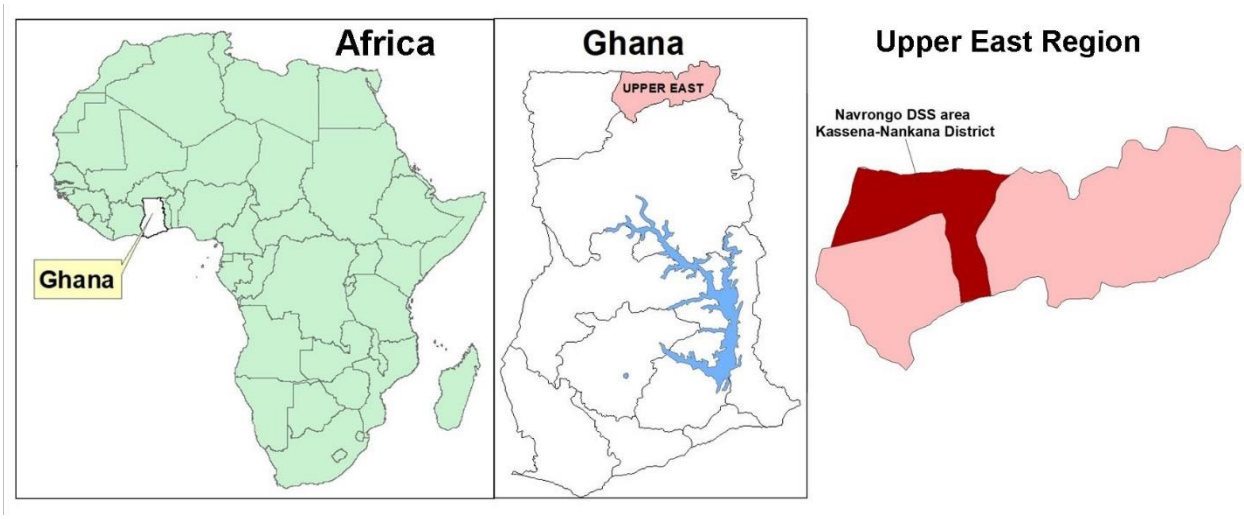


Figure 1: location of the study area (NHDSS site) on a map of Upper, Upper east on a map of Ghana and Ghana on the map of Africa.

The vegetation of the study area is guinea Savannah in nature with a short rainy season from May to September and a prolonged dry season the rest of the months. The area has an annual mean rainfall of approximately 1300 mm with mean monthly temperatures ranging from 22.88^{o}C to 34.48^{o}C (57). Economically, the people in the study area are engaged in petty trading, agriculture and tourism. The surveillance area is divided into five geographic zones (East, West, South, North and Central). The zones were further divided into 247 clusters (Figure2). Each cluster has an average of 70 compounds.

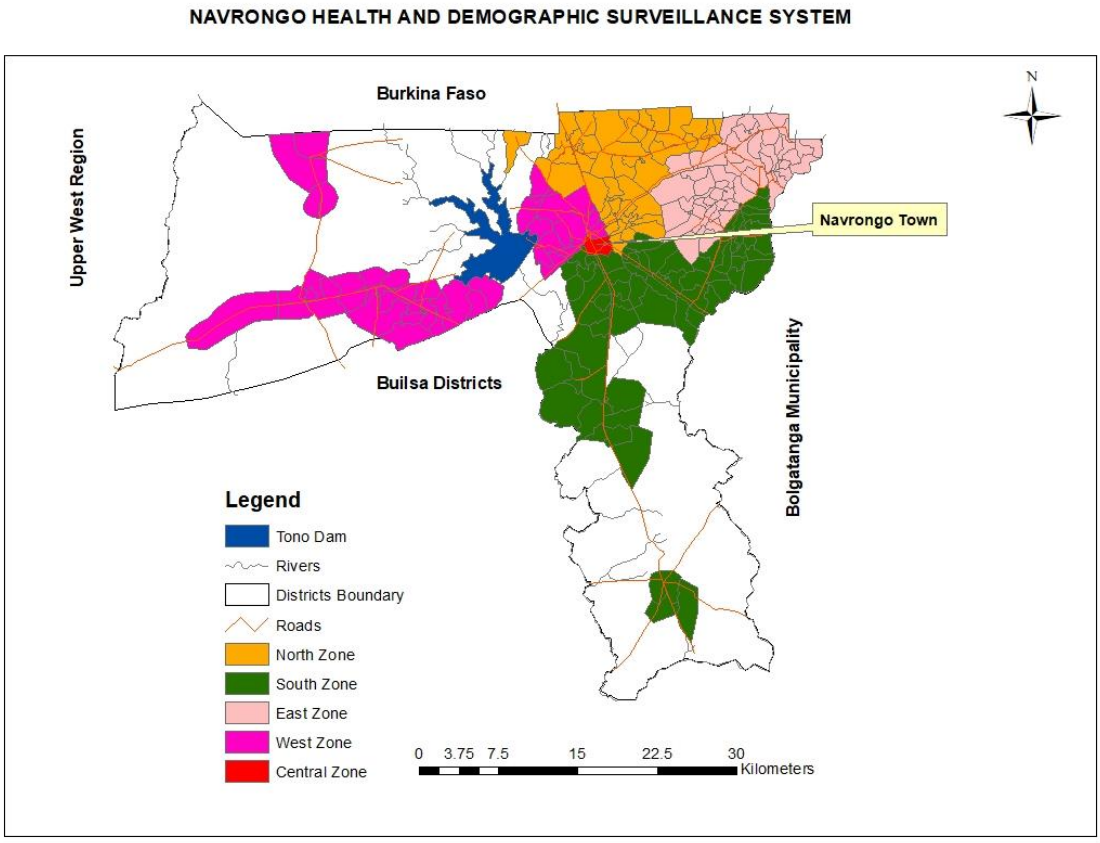


Figure 2: Navrongo HDSS coverage area in the Kassena-Nankana districts.

The study area has a hospital which serves as a referral facility. In addition to the hospital there are seven health centers, 27 health compounds with 27 CHPS compounds with resident health workers and several other primary health care clinics. It also includes several educational institutions ranging from basic school level to University level with a Nursing training college (57).

2.2 Study Design

The study was a secondary analysis of a prospectively collected longitudinal data. A statistical analysis of under-five mortality of data that was collected from 1st January 2007 to 31st December 2012 (A period of six years) was conducted. The study leverages on the rich database of the NHDSS, which routinely and continually collects and records births, deaths, marriages, in- and out- migration and other socio-demographic data on households and individuals.

2.3 The Rural NHDSS

The Navrongo HDSS commenced in 1993 where all residents of 45 rural communities within the NHDSS site were enumerated for the first time. Every individual is given a unique identification which is assigned along with a name, DOB, sex and relation to the household head. After the baseline census, every household is visited quarterly by a well-trained interviewer to record births, deaths, in-and out-migrations and pregnancies. Each visit is termed an HDSS round and as at December 2012, 69 rounds had been conducted. All the information is captured into a database system. The current database system for capturing the HDSS information is the Household Registration System II (HRS2).

The HRS2 is a structured system, designed and programmed through the relational database package, using Visual FoxPro (58). A person is registered into the HDSS if such person resided within the Demographic Surveillance Area (DSA) for at least 4 months prior to an update round. Such a person is classified as an external in-migrant and he/she is coded as "Entry" in the database. Those who were present during the baseline were coded as "Enumerated.

2.4.1 Demography

The NHDSS had a total population of 153,000 under continuous demographic surveillance with 33,600 households as at 2012 (57). About 10.0% of the households in the NHDSS catchment area were living in the district capital, Navrongo (8). The average household and compound sizes were five and nine respectively (57). The ratio of males to females was 92:100 (57). Over 70% of individuals in the Kassena-Nankana East and West districts were illiterate (59).

2.4.2 The NHDSS Verbal Autopsy System

Verbal Autopsy (VA) tools have been used to assess causes of death among under-fives (60–62). The VA tool is a questionnaire with several structured questions on circumstances leading to deaths in the household. Additional section of the questionnaire allows for detailed verbal narrations of conditions that underpinned the death. Experienced field supervisors trained by the NHRC conducted the interviews. In the case of death of a child, the field supervisor empathetically interviewed the immediate caregiver of the child to elicit relevant cause and circumstances of death. VA interviews were typically conducted approximately six months after the occurrence of death. This interval between death and scheduled interview was a trade-off between minimizing the risk of emotional trauma to the respondents who had lost a loved one by interviewing them too soon after a death, and to decrease the likelihood of recall bias by interviewing them too late

(63, 64). Data collection was rigorously supervised. The VA forms where then given to 3 physicians who independently reviewed and assigned cause of death (COD). The COD corresponds to a 3-digit code which is in line with the international Statistical Classification of diseases and health related conditions (65). Two of the physicians must agree to an underlining COD for a diagnosis to be established. Where there is disagreement among all three, the form is submitted to two physicians who jointly review the circumstances leading to death and assign a COD. In an event there is no consensus after a VA information has been made available, the COD is declared Undetermined. While in cases where there is limited or no VA information available to enable for the establishment of a COD it is declared unknown.

2.5 Study Population

The target population was all under-five children registered at the Navrongo Health and Demographic Surveillance System (NHDSS) between 2007 and 2012.

2.6 Sample Size

In all, 20,651 under-five children recorded in the NHDSS between 2007 and 2012, including 1,010 deaths were included in this study.

2.7 Inclusion and Exclusion Criteria

Only under-five children who were born in the study area between January 2007 and December 2012 were included in the study. Children who were born in the study area but have missing data on key variables were excluded from the study.

2.8 Variable Measurement and Data Sources

2.8.1 Exposure Variables

The exposure variables for this study were considered as potential risk factors for under-five mortality. During the 2007 to 2012 period, baseline factors such as Socio-economic status (SES), age, sex, education, birth order, marital status, mother's age, ethnicity, religion, residence, place of death and place of birth were collected. SES was measured by calculating a wealth index based on household assets ownership and availability of utilities, using weights derived through principal component analysis (66). The wealth index was divided into five quintiles: poorest, very poor, poor, less poor and least poor. The SES was calculated at the household level and assigned to individuals from same household as a proxy. All children were followed-up from birth until they reached age 5, died, migrated out of the study area or were censored on 31st Dec. Age at death was also calculated for those who died during the analysis period as the difference between date of birth and date of death. Maternal education was measured by the level reached and classified into three categories: 'No Education', 'primary or junior secondary school level' and 'secondary and beyond level of education'. This educational classification has been previously employed by Kanmiki *et al* (2014) and Welaga *et al* (2013).

Although Welaga *et al.* (2013) categorized place of birth into "health facility" and "elsewhere (outside health facility)", in this study, place of birth was categorized into three groups, namely "health facility", "home" and "elsewhere". This grouping was necessary since most people died at home but deaths due to accidents and injuries occurred mostly elsewhere (67).

Mode of entry or entry type depicted how the individual got recruited by the NHDSS for the very first time. "In-migrants" were those who were not present during the baseline data collection

whereas “enumeration” was for those who were present during the baseline data collection. In this study, all the children were followed-up from birth since the analysis was limited to children born in the demographic surveillance area.

Sex was coded conventionally as male and female. Residence was coded as whether you lived in Rural or Urban area. The individual’s marital status was also coded as married and unmarried. Religion and ethnicity were the other variables of interest which were included in the study. The variables included in this study were selected based on published literature.

Table 2.1 Independent variables considered

Variable	**Type**	**Labels (Values)**
Under-five characteristics		
Birth order of child	Categorical	First child; second to fourth and fifth and above
Sex of child	Categorical	Female=1; Male=2
Marital status of mother's	Categorical	Married=1; Not married=2
Ethnicity	Categorical	Kassem=1; Nankam=2; Buli=3; Other=4
Mother's Age (in years)	Categorical	<19=1; 20-34=2; 35+=3
Religion	Categorical	Traditional=1; Christianity=2; Islam=4; Other=5
Residence	Categorical	Urban=1; Rural=2
Socioeconomic status of the household	Categorical	Poorest=1; Poorer=2; Poor=3; Less poor=4; least poor=5
Education level of the mother	Categorical	No education=1; Primary/JSS=2; Sec/tertiary=3
Birth Place	Categorical	Health facility=1; Home/elsewhere=2
Twining Status	Categorical	Singleton=1; Multiple=2
Death place	Categorical	Hospital=1; Health Centre=2; Home=3; Other=4

2.8.2 Outcome Variable

The study outcome variable was survival status, which is binary. A participant can either be alive or dead. Under-five mortality rates were directly estimated by dividing the number of deaths of children aged 0-59 months by person years observed for a specific period of time and expressed per 1000 person years of observation (68,69)

For the cause-specific analysis, cause of death was assigned to a death for which VA was successfully conducted. The process of assigning a cause of death had previously been described under NHDSS VA system above (section 2.4.2). The individual causes of death were re-classified into broad causes of death as described by Chasin et al (1992) and utilized by other researchers (48,60,70,71). These broad classifications of causes of deaths were: Communicable diseases (CD), Non-communicable diseases (NCD), Accidents/Injuries and undetermined causes of death.

2.9 Data Management

Variables needed to answer the research questions were extracted from the database developed in Visual FoxPro platform (see section 2.2 above) and transferred into STATA version 15 (Statacorp USA) using a STATA transfer software version for analysis.

The variables were selected from four different tables, namely individual, residence, death and household assets tables. The total number of deaths was obtained from the death table of all under-five children who reside in the demographic surveillance area. All children born between 1st January 2007 and 31st December 2012 in the demographic surveillance area were included in the analysis. From this dataset, those whose exit dates were before the start date (1st January 2007) or those whose entry date was after end date of the study (31st December 2012) were excluded from the final analysis.

All these datasets were linked by household or unique identifiers to form one dataset for the analysis. The extracted data was cleaned for missing values, anomalies and internal consistency of responses. Hard copies of the completed questionnaires were also used for references and validation during the data cleaning process.

In assessing the leading causes of under-five deaths in the study area, a suit of computer models (InterVA4) was used to assign probable causes of death for all under-five children in the study who died during follow-up (72). InterVA4 analyses the signs and symptoms prior to death to produce causes of death. The causes of death were further classified into three broad groups consisting of communicable disease, non-communicable disease and accident/injuries. Birth order was also categorized into three groups: first birth, 2-4 births and 5 and above births.

2.10 Data Analysis

Data analysis was done using STATA 15. Basic tabulations were used to assess the frequencies and percentage distribution of the background characteristics of the children included in the study. In addition, Pearson's Chi-squares (χ^2) test was used to assess the association between the survival status and each socio-demographic variable.

2.10.1 Leading causes of under-five deaths in the Kassena-Nankana districts between 2007 and 2012

InterVA4 was used to assign the probable causes of death of each child using verbal autopsy data. Basic frequencies were used to identify the leading causes of under-five deaths in the study area. The individual causes of deaths were further categorized into three broad categories namely, communicable diseases, non-communicable diseases and Accidents/Injuries. Those without an assigned cause of death were classified as "undetermined". The percentage distribution of each

broad cause of death was calculated. Furthermore, the broad leading causes of death were then stratified by gender and other socio-demographic characteristics.

2.10.2 Spatial Variation in under-five mortality

To examine the spatial variation in under-five mortality, choropleth maps were used to depict the geographical distribution of under-five deaths across the study area. The global Moran's Index statistics was also used to ascertain whether there was a significant clustering of under-five deaths across the study area. The Anselin Moran's Index was then used to detect the local clustering and to identify significant hotspots and cold spots.

Spatial weighting matrices

Both the exploratory and inferential spatial analysis requires creating a spatial weighting matrix. The weighting matrix defines the spatial autocorrelation between measurements at different locations. The definition of the autocorrelation was based on Tobler's first law of geography which states that "everything is related to everything else but near things are more related than distant things". Therefore, to determine the relationship between nearby observation, we parameterized the Tobler's law by creating a spatial weighting matrix using the DHS cluster shape file with the number of cluster (247) as the size of the matrix. For the purposes of this study an inverse distance weighting matrix, W was created. In an inverse-distance matrix W , $w_{ij} = 1/D_{ij}$ where D_{ij} is the distance between area *i* and area *j*

2.10.3 Moran's Index

To determine whether under-five deaths is clustered, dispersed or randomly distributed in the study area, the Moran's Global index statistic was used. The Moran's I is given as

$$I = \frac{n}{W} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=1}^{n} z_i^2}$$

where z_i is the deviation of a measurement at area i from its mean ($x_j - \bar{x}$), $w_{i,j}$is the spatial weight between measurements at location *i* and location *j*,

n is the total number of clusters, and W is the weighting matrix.

The calculated value for the Moran's I statistic is between -1 and 1. A value close to 1 indicates that the distribution of under-five death is clustered, while values close to -1 and zero indicate dispersion or randomness in the distribution of under-five death in the study area. We rejected the null hypothesis and conclude that, there was evidence of clustering in the distribution of under-five deaths in the study area using ArcGIS, when the p-value associated with the Moran's I value was < 0.05.

*2.10.4 Getis-Ord General G and Getis-Ord Gi**

To explore the concentration of high or low mortality of under-five in the study area we used Getis-Ord General G and Getis-Ord Gi*. The Getis-Ord General G statistic is an inferential statistics measure and it is given as:

$$G^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{x} \sum_{j=1}^{n} w_{i,j}}{s \sqrt{\frac{n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j} \right)^2}{n-1}}}$$

Where $x_j$is the value for measurement at location j $w_{i,j}$is the spatial weight matrix and n is the total number of clusters and :

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j}{n} - (\bar{X})^2}$$

For a cluster to be identified as a hot spot, a z-score is computed for each cluster. The resultant z-score and p-value indicate where the mortality is spatially clustered - the higher (or lower) the z-score, the stronger the intensity of the clustering. A z-score near zero indicates no apparent clustering within the study area. A positive Z score indicates clustering of high values. A negative Z scores indicates clustering of low values. If the p-value associated with the observed z-score is less than 0.05, the null hypothesis is rejected and we conclude that, the likelihood of the observed hot spot is too rare to be attributed to chance. The opposite is also true for cold spot (73). Getis-Ord Gi was later used to identify the correlated clusters.

2.10.5 Risk factors associated with under-five deaths

Since our data was from a longitudinal cohort study with continuous follow-up from birth, a time to event analysis (from birth or recruitment to death) was conducted to assess the association between baseline socio-demographic characteristics and under-five mortality. Children who had the event (death) within 59 months of birth were coded as 1 while children who survived beyond 59 months were right censored. Furthermore, children who were lost to follow-up or who were transferred out of the catchment area of the study were also right censored.

Kaplan Meir survival curves were used to depict the overall survival experience of the under-five cohort. Afterwards, Kaplan Meir survival curves were used to assess the survival experience of

the children by socio-demographic background characteristics. Equality of survival experience by background variables was assessed using a log rank test.

To determine the association between baseline socio-demographic factors and under-five mortality, univariable and multivariable Cox proportional hazard regression models were used using variables outlined in the analytical framework.

Cox regression models: analysing the effect of several risk factors on survival

$$H(t) = H_o(t) \times \exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k) \quad (1)$$

$$\frac{H(t)}{H_0(t)} = \exp(\beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k) \quad (2)$$

where

H(t) is the hazard function, $\{H_o(t) \times \exp(\beta_o)\}$ is the baseline hazard at time t, representing the hazard for a person with value 0 for all predictors

- $\frac{H(t)}{H_0(t)}$ is the hazard ratio
- $X_1 \ldots X_k$ are a collection of predictor variables, the coefficient of $\beta_1 \ldots \beta_k$ are estimated by cox regression model

Variables with P-values < 0.20 after univariable analysis were then included in the multivariable model, using a stepwise forward regression modelling starting with variable with the least Univariable P-value. Akaike information criterion (AIC) and Bayesian information criteria were used for the model selection until a parsimonious model was achieved. Models with the least AIC and BIC were presumed as the best model. To correct for cluster effect, 'robust' option was added to the command in Stata so as to produce valid standard errors. Post estimation Global test of Schoenfeld and graphical description were conducted to check for any violation of the assumptions

of Cox proportional hazard modeling. Any variable with value less than 0.05 were assumed to violate the assumption and were dropped from the model. Furthermore, the graphical representation (stphplot) was also checked to confirm the assumption of proportionality. Crude and adjusted hazard ratios were then reported. Statistical significance was considered at 5% significance level ($P<0.05$).

2.11 Ethical Considerations

Authorization and access to data was sought and approved by the Navrongo Health Research Centre, the custodian of the data (appendix 2). Ethical clearance (M181193 appendix 3) was given by the Human Research Ethics Committee (Medical), University of the Witwatersrand, Johannesburg before the commencement of the analyses. Ethical approval for collection of the original data by the NDSS was given by the NHRC Institutional Review Board (IRB). The extracted data was used strictly for the purposes of this study. Confidentiality and anonymity were maintained by ensuring that unique identifiers were used instead of names of individuals.

CHAPTER 3: RESULTS

This chapter reports the results from the analysis of the population-based longitudinal data covering a period of six years (2007-2012) with under-five children as the target population. It has been divided into five main parts. It begins with a descriptive analysis of the background characteristics of the study participants. The second part presents results on the causes of under-five deaths in the Navrongo HDSS area for the six-year period. The third part shows the trends in overall under-five mortality rates and Kaplan-Meier survival estimates, expressed per thousand person's year of observations (PYO) for the follow-up period. The chapter also presents the cause-

specific mortality rates for the period of observation. The results from the spatial distribution of under-five deaths (including significant hot and cold spots) are presented in part four. The final part of this section involved identification of the risk factors which were associated with under-five cause specific mortality using Cox proportional hazard models.

3.1 Background Characteristics of the study participants

Table 3.1 shows the background characteristics of the study participants. Twenty-thousand six hundred and fifty-one children under the age of five years were followed up from January 1, 2007 to December 31, 2012. The frequency distribution of female and male children involved in the study were similar (49.9% vs 50.1% respectively). Majority (75.7%) of the mothers were married. The two main ethnic groups were the Kassem (50.6%) and the Nankan (45.0%). Approximately 67% of the mothers were aged between 20 and 34 years old. Christianity (50.4%) and traditionalist (42.1%) were the dominant religious groups. About 86.6% dwell in rural setting. In all, 29.8% of households were in the fourth and fifth wealth quintiles. About 33.5% (6929) of the children in the study were delivered at home or elsewhere over the 6-year period. Ninety-five percent (19,715) of the deliveries were singleton births.

Table 3. 1: Distribution of the background characteristics of under-five children included in the study in Navrongo HDSS, Ghana: 2007-2012

Factors	Level	N=20,651	Percent
Birth order of child	1	6,355	30.8
	2-4	9,889	47.9
	5 or more	4,407	21.3
Sex of child			
	Female	10,307	49.9
	Male	10,344	50.1
Marital status of mother's			
	Married	15,631	75.7
	Not married	5,020	24.3
Ethnicity of mother			

	Kassem	10,446	50.6
	Nankan	9,292	45
	Buli	372	1.8
	Other	541	2.6
Mother's Age			
	<=19	2,369	11.5
	20-34	13,851	67
	35 or more	4,431	21.5
Religion of mother			
	Traditional	8,687	42.1
	Christianity	10,409	50.4
	Islam	1,507	7.3
	Other	48	0.2
Residence of mother			
	Urban	2,774	13.4
	Rural	17,877	86.6
Socioeconomic status of the household			
	Poorest	5,861	28.4
	Poorer	4,735	22.9
	poor	3,911	18.9
	Less poor	3,791	18.4
	Least poor	2,353	11.4
Education Level of the mother			
	No education	5,999	29
	Primary/JSS	11,597	56.2
	Secondary/tertiary	3,055	14.8
Birth Place			
	Health Facility	13,722	66.5
	Home/Somewhere	6,929	33.5
Twinning status			
	Singleton	19,715	95.5
	Multiple	936	4.5

JSS-Junior Secondary School

3.2 Under-five Mortality in the NHDSS

During the study period, 1010 under-five deaths were recorded. Verbal autopsies were successfully conducted on 911 (90.2%) deaths and were assigned a probable cause of death.

3.2.1 Percentage distribution of under-five deaths by background characteristics

The result of the bivariate analysis of ever experiencing an under-five death at household level and background characteristics are shown in Table 3.2. Of the 20651 children included in the analysis, 549 (5.3%) males and 461 (4.5%) females died over the six-year follow-up period. There was a statistically significant association between sex of child and under-five deaths (P<0.001, chi2=16.78, df=1). Marital status was also associated with under-five deaths with the proportion of under-five deaths among children of mothers who were not married being higher than those married (P<0.001, chi2=16.79 df=1). Ethnicity of the participant was not associated with under-five deaths (Table 3.2). Children born to mothers aged 35 years or above were more likely to experience under-five deaths compared to the younger age groups (P<0.001, chi2=22.47, df=2). Religion of the participants was significantly associated with under-five deaths with traditionalists having a higher proportion of under-five deaths than those who practiced Christianity and Islamic religions (P=0.001, chi2=16.47, df=3). Place of residence was associated with under-five deaths with rural dwellers having slightly higher proportion of under-five deaths than urban dwellers (P=0.007, chi2=7.36, df=1). In addition, socio-economic status, maternal education, birth place and twinning status were all significantly associated with survival status in the bivariate analysis (Table 3.2). The proportion of under-five deaths in the fifth quintile (least poor) was the least among the wealth quintiles. Similarly, deaths among under-five children differed significantly with the level of the mother's education, with children born to mothers with higher education having relatively low under-five mortality rates. Children delivered at home had higher under-five mortality rates than their counterparts delivered in health facilities. Multiple deliveries had higher percentage of under-five deaths than singleton deliveries. Children with birth order of 5 or more have higher proportion of under-five deaths than those with birth order of one (P<0.001, chi2=19.12, df =2).

Table 3. 2: Under-five deaths by background characteristics in Navrongo Health and Demographic Surveillance System in Ghana, 2007-2012

Factors	Category	No. of children	Under-five Deaths n(%)	X^2 statistic, d.f., p-value
Sex				
	Female	10,307	461(4.5)	7.734
	Male	10,344	549(5.3)	1, <0.005
Marital status of mother				
	Married	15,631	710(4.5)	16.794
	Not married	5,020	300(6.0)	1, < 0.001
Ethnicity of mother				
	Kassem	10,446	498(4.8)	5.299
	Nankam	9,292	453(4.9)	3, 0.151
	Buli	372	23(6.2)	
	Other	541	36(6.7)	
Maternal age				
	<19	2,369	129(5.5)	22.921
	20-34	13,851	610(4.4)	2, <0.001
	35 or more	4,431	271(6.1)	
Religion of mother				
	Traditional	8,687	481(5.5)	16.468
	Christianity	10,409	449(4.3)	3, 0.001
	Islam	1,507	79(5.2)	
	Other	48	1(2.1)	
Residence of mother				
	Urban	2,774	107(3.9)	7.359
	Rural	17,877	903(5.1)	1, 0.007
Wealth quintile				
	Poorest	5,861	338(5.8)	28.807
	Poorer	4,735	236(5.0)	4, <0.001
	Poor	3,911	204(5.2)	
	Less poor	3,791	154(4.1)	
	Least poor	2,353	78(3.3)	
Maternal education				
	No education	5,999	341(5.7)	26.020
	Primary/JSS	11,597	570(4.9)	2, <0.001
	Secondary/tertiary	3,055	99(3.2)	
Birth Place				

	Health Facility	13,722	547(4.0)	71.930
	Home/Somewhere	6,929	463(6.7)	1, <0.001
Twinning status				
	Singleton	19,715	927(4.7)	33.332
	Multiple	936	83(8.9)	1, <0.001
Birth order of child				
	1-	6,355	301(4.7)	19.1291
	2-4	9889	439(4.4)	2, <0.001
	5 or more	4,407	270(6.1)	
TOTAL		**20,651**	**1,010(4.9)**	

3.2.2 Causes of Death

3.2.2a Causes of neonatal deaths

Over the six-year period, a total of 309 neonatal deaths were recorded. The four leading causes of neonatal deaths in the study area were Neonatal pneumonia (29%), Prematurity (25%), Birth asphyxia (23%) and other unspecified causes (18%). Most of the neonatal deaths (71%) occurred in the early neonatal period of 0 to 6 days. Birth asphyxia (28%), neonatal pneumonia (24%) and prematurity (25%) were the major causes of early neonatal deaths. Neonatal pneumonia accounted for 40% of all the late neonatal deaths (see Figure 3.1).

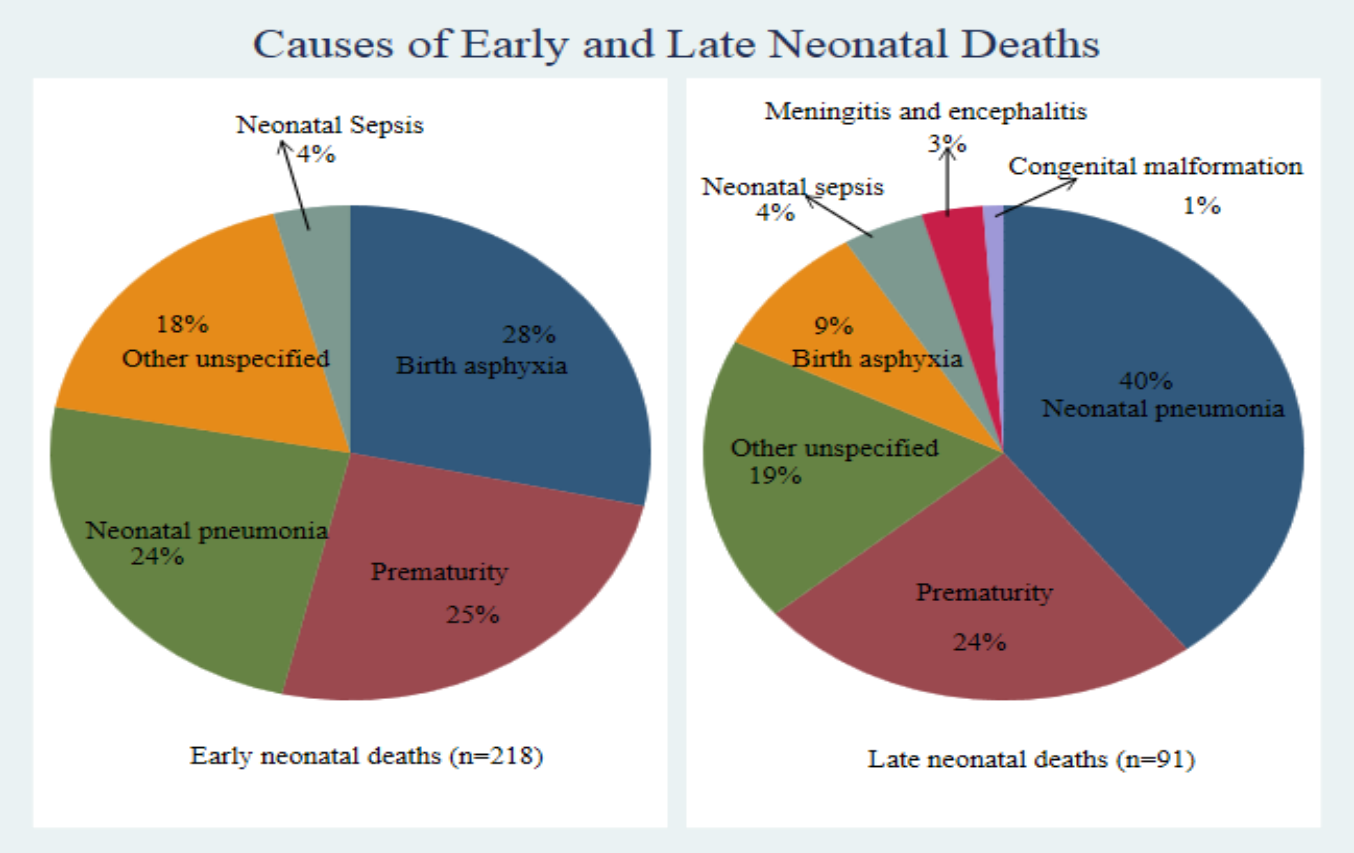


Figure 3. 1: Causes of Early and Late Neonatal deaths in Kassena-Nankana districts of Ghana, 2007-2012.

3.2.2b Causes of Under-five Deaths

Of all the 1010 under-five deaths in the study area, 94% had verbal autopsies done and 6% of the causes of death were classified as undetermined. Undetermined cases came about as a result of either the information collected for coding being insufficient or it was too complex to ascertain the right specific cause of death. Table 3.3 gives an overview of the top five causes of deaths among under-five children in the NHDSS from 2007-2012. Overall, 30% of the 1010 deaths were attributed to malaria and 18% to Acute Respiratory Infections (ARI) (including Pneumonia). Besides malaria and ARI, Neonatal Pneumonia (15%), HIV/AIDS related causes (14%) and prematurity (13%) were among the top 5 causes of under-five deaths in the study area. When the causes of under-five deaths were reviewed separately by sex: Prematurity, ARI, Neonatal

Pneumonia, HIV/AIDs related and Malaria in that order respectively constituted the top five causes of under-five deaths among males. Among females, Malaria, HIV/AIDs related causes, Neonatal Pneumonia, ARI and Prematurity in that order constituted the top five causes of under-five deaths (Table 3.3).

Table 3. 3: Top Five Narrow Specific-Causes of Deaths in Navrongo Health Demographic Surveillance System in Ghana by Sex, 2007-2012

Ranks	Overall		Sex of child	
			Male	Female
	Causes	Total	n (%)	n (%)
1	Malaria	187	90(48.1)	97(51.9)
2	ARI (Pneumonia)	110	59(53.6)	51(46.4)
3	Neonatal pneumonia	91	46(50.5)	45(49.5)
4	HIV/AIDS related	87	43(49.4)	44(50.6)
5	Prematurity	80	49(61.2)	31(38.8)
6	Undetermined	52	31(59.6)	21(40.4)
	Total	607	318(52.4)	289(47.6)

X^2 =5.47 p-value=0.362

Top Five Causes of Death by age group, 2007-2012

Table 3.4 shows the causes of under-five deaths by different age groups. Children within the age group of 1 to 4 years died mostly from malaria (73%), while children within the age group of 1-11 months died mostly from ARI (Pneumonia) (87%). Most of the neonatal pneumonia deaths (98%) occurred among children aged 0-27days. There was a statistically significant association between cause of death and age group at death (Table 3.4).

Table 3. 4: Top Five Causes of Death by age group in Navrongo Health Demographic Surveillance System, 2007-2012

Overall		Age at death		
		0-27days	1-11moths	1-4years
Causes	**Total**	**n(%)**	**n(%)**	**n(%)**
Malaria	187	0(0.0)	51(27.3)	136(72.7)
ARI (Pneumonia)	110	0(0.0)	96(87.3)	14(12.7)
Neonatal pneumonia	91	89(97.8)	2(2.2)	0(0.0)
HIV/AIDS related	87	0(0.0)	31(35.6)	56(64.4)
Prematurity	80	77(96.2)	3(3.8)	0(0.0)
Undetermined	52	1(1.9)	21(40.4)	30(57.7)
Total	607	167(27.5)	204(33.6)	236938.9)

X^2 =724.28 p-value<0.001

3.2.2c Broad causes of under-five deaths

Causes of death were broadly classified into Communicable diseases, Non-communicable diseases, Accidents (Injuries) and Malnutrition. Figure 3.2 shows that 66% of the deaths were attributed to communicable causes, 20% were from Non-communicable causes, 11% were from Accidents or Injuries and 3% were due to Malnutrition.

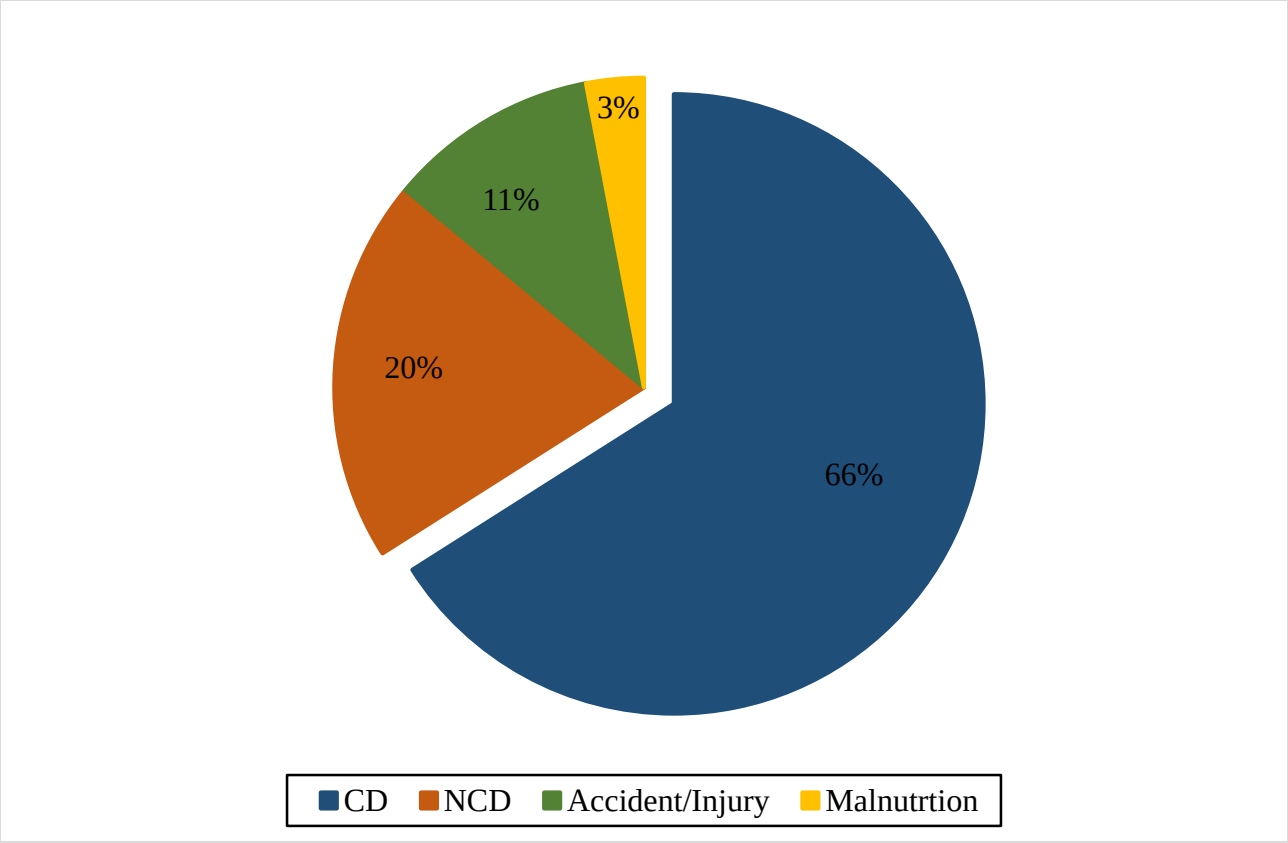


Figure 3. 2: Broad causes of under-five deaths in Navrongo HDSS, 2007-2012.

Broad Causes of Under-five Deaths by sex, 2007-2012

The study also showed, as presented in Table 3.5, that 59% of males and 67% of females died from communicable diseases while 19% of males and 18% of females died from non-communicable diseases. Additionally, the proportion of deaths from accidents or injuries among males was 10% and 8% among females. Deaths classified as "undetermined" were 5.4% among males and 4.8% among females.

Table 3. 5: Broad Causes of Under-five Deaths by Sex in Navrongo Health Demographic Surveillance System, 2007-2012

Causes of Death	Total (%)	Sex	
		Male n(%)	**Female n(%)**
Communicable	604 (62.7)	308 (59.1)	296 (67.0)
Non-communicable	185 (19.2)	105 (20.2)	80 (18.1)
Accident/Injuries	97 (10.1)	60 (11.5)	37 (8.4)
Malnutrition	25 (2.6)	17 (3.3)	8 (1.8)
Undetermined	52 (5.4)	31 (6.0)	21 (4.8)
Total	963 (100)	521(100)	442 (100)

Proportion of under-five deaths by broad categorized cause & place of death, 2007-2012

Among those who died from communicable diseases, 31% of the deaths were attributed to malaria, 18% were due to ARI including (pneumonia), and 15% were due to Neonatal pneumonia. About 42% of the (604) communicable causes occurred among children aged 1-4 years, followed by those aged 1-11 months (41%) and then 0-27 days (17%) (See Appendix A for a table describing deaths due to broad causes of death by age).

Among those who died from non-communicable causes, it was mostly due to prematurity (43%) and followed by congenital malformation (14%). The rest of the other non-communicable causes account for small fractions. About 72% of the (185) non-communicable causes occurred among those aged 0-27 days. Also, of the 97 deaths that were due to accident/injuries, 72% were due to birth asphyxia, followed by accidental drowning and submersion (16%) and road traffic accidents (4%). Most of these accident/injuries occurred among the children aged 0-27 days.

A large proportion of deaths occurred at home as shown by Figure 3.3 A higher proportion of under-five deaths from communicable, non-communicable and accident/injuries causes occurred more at home than health facilities, while undetermined causes occurred more at the health facilities than home.

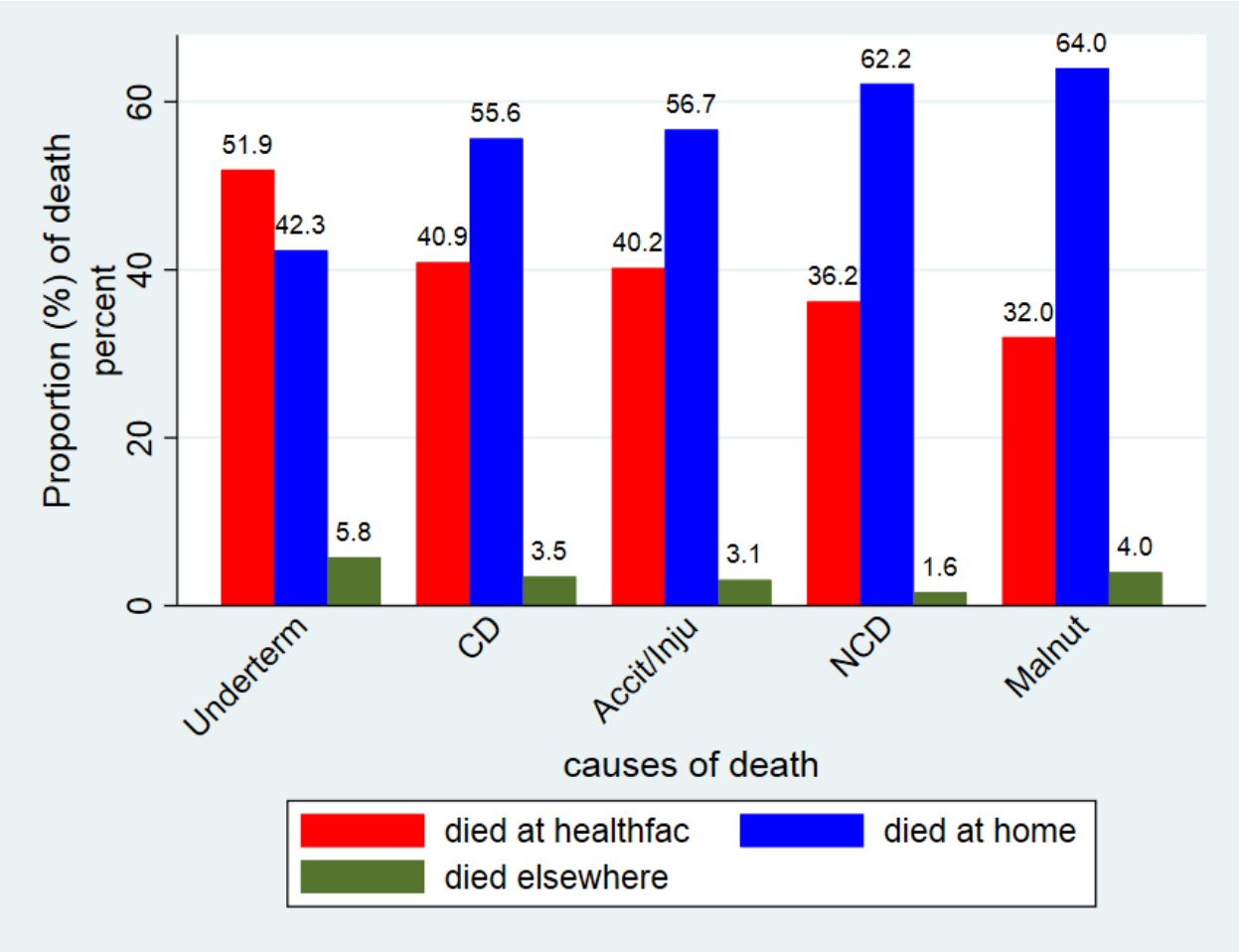


Figure 3. 3: proportion of under-five deaths by broad categorized cause & place of death, 2007-2012.

3.3 Under-five Mortality Rates

A total of 20,651 children followed up for the 6year period yielded 51,783 person years of observation (PYO). The number of under-five deaths registered during the follow up period was 1010, which is about 4% of the total cohort. The mortality rates are reported per 1000 person years of exposure. Overall, under-five mortality rate was 19.5 per 1000 person years of observation (PYO). Table 3.6 summarizes the mortality rates by background characteristics. The results showed that under-five mortality rate was higher among males [21.1 (95% CI: 19.4, 22.9) per 1000 PYO] compared with females [17.9 (95% CI: 16.4, 19.6) per 1000 PYO]. Under-five mortality rate among children born to mothers who were not married was higher [25.1 (95% CI: 22.5, 28.2) per 1000 PYO] than those whose mothers were married (Table 3.6). Under-five mortality rate was 19.6 (95% CI: 17.8, 21.4) per 1000 PYO among the Nankam and 18.8 (95% CI: 17.2, 20.5) per 1000 PYO among the Kassem ethnic group. Mortality among children born to mothers aged between 20 and 34 was the lowest [17.7 (95% CI: 16.4, 19.2) per 1000 PYO] compared to those whose mothers were either below 20 years or older than 34 years. Under-five mortality rate among children in rural settings was higher than the rate in the urban settings (Table 3.6). Generally, there was a decrease in under-five mortality rate with an increase in SES status, with children in the poorest quintile recording the highest under-five mortality rate [22.5 (95% CI: 20.2, 25.0) per 1000 PYO] and lowest rates among children in the least poor quintile [13.8 (95% CI: 11.0, 17.2) per 1000 PYO]. Similarly, children born to mothers with no education recorded the highest under-five mortality [21.4 per 1000 PYO] and children to mothers with secondary or tertiary education recorded the lowest under-five mortality rate [13.8 (95% CI: 11.3, 16.8) per 1000 PYO]. Under-five mortality rate among multiple births [38.4 per 1000 PYO] was about twice the rates of singletons. Under-five mortality rate was slightly lower among children born to mothers with 2-5 children [17.2 (95% CI: 15.7, 18.9) per 1000 PYO] compared to the other groups (Table 3.6).

Table 3. 6: Under-five Mortality rates per 1000 person by background characteristics in Navrongo, 2007-2012

Factor	Category	deaths	Person years	Mortality rate (95%CI)
Sex of child				
	Female	461	25732.3	17.9 (16.4-19.6)
	Male	549	26061	21.1 (19.4-22.9)
Marital status of mother				
	Married	710	39861	17.8 (16.5-19.2)
	Not married	300	11932.3	25.1 (22.5-28.2)
Ethnicity of mother				
	Kassem	498	26534.1	18.8 (17.2-20.5)
	Nankan	453	23165.6	19.6 (17.8-21.4)
	Buli	23	896.6	25.7 (17.0-38.6)
	Other	36	1197	30.1 (21.7-41.7)
Mother's Age				
	<19	129	5399.6	23.9 (20.1-28.4)
	20-34	610	34378.5	17.7 (16.4-19.2)
	35 or more	271	12015.2	22.6 (20.0-25.4)
Religion of mother				
	Traditional	481	21763	22.1 (20.2-24.2)
	Christianity	449	26334.5	17.0 (15.5-18.7)
	Islam	79	3579.7	22.1 (17.7-27.5)
	Other	1	116.1	8.6 (1.2-61.2)
Residence of mother				
	Urban	107	6741.8	15.9 (13.1-19.2)
	Rural	903	45051.5	20.0 (18.8-21.4)
Wealth quintile				
	Poorest	338	15042.8	22.5 (20.2-25.0)
	Poorer	236	11939	19.8 (17.4-22.5)
	Poor	204	9709.8	21.0 (18.3-24.1)
	Less poor	154	9442.3	16.3 (13.9-19.1)
	Least poor	78	5659.4	13.8 (11.0-17.2)
Maternal education				
	No education	341	15950.2	21.4 (19.2-23.8)
	Primary/JSS	570	28675.1	19.9 (18.3-21.6)
	Secondary/tertiary	99	7168	13.8 (11.3-16.8)
Birth Place				

	Health Facility	547	29692.5	18.4 (16.9-20.0)
	Home/Somewhere	463	22100.8	20.9 (19.1-22.9)
Twinning status				
	Singleton	927	49630.2	18.7 (17.5-19.9)
	Multiple	83	2163.1	38.4 (30.9-47.6)
Birth order of child				
	1-	301	14110.9	21.3 (19.1-23.9)
	2-4	439	25459.7	17.2 (15.7-18.9)
	5 or more	270	12222.7	22.1 (19.6-24.9)

3.3.1 Survival Probabilities

The Survival analysis showed that under-five male children had lower survival rate compared with females. A log rank test shows that there was a statistically significant difference in survivorship between under-five male and female children in the cohort ($p= 0.008$). Children born to mothers aged 20 - 30 years had the highest chance of survival. The study also found that, the higher the level of education of the mother, the higher the survival rate (Figure 3.4).

The results showed that multiple births had lower survival rate compared to singleton birth (Figure 3.4). These differences were statistically significant using the log-rank test for equality of survival functions ($p<0.001$). Figure 3.4 shows the Kaplan-Meier survival curves for sex of the child, maternal age, level of education of the mother and place of birth.

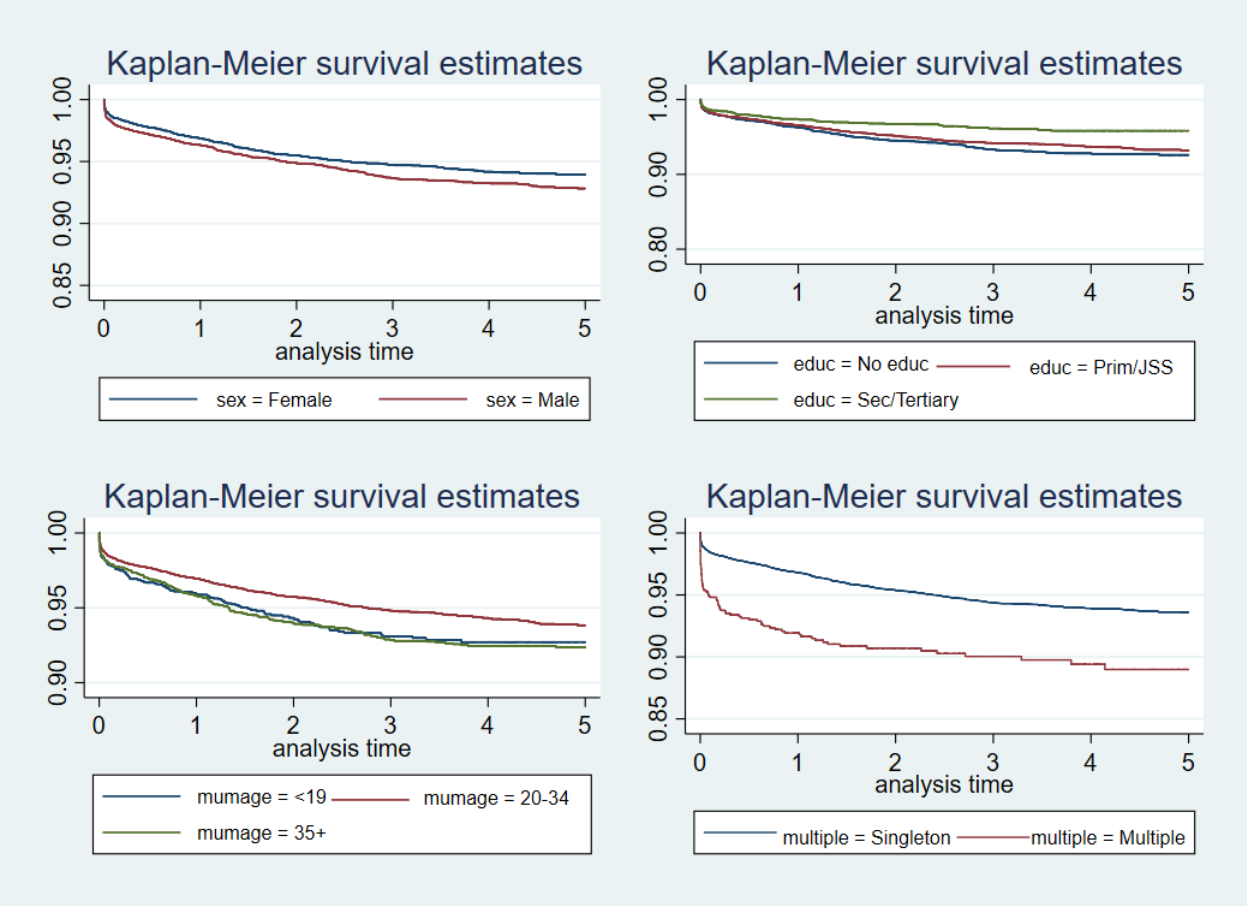


Figure 3. 4: Kaplan Meier Survival curves for under-five in the NHDSS, 2007-2012

3.4 Explanatory Spatial Analysis

The distributions of under-five deaths by cluster level are presented using choropleth maps. Global and local spatial autocorrelation analysis techniques were employed to evaluate the existence of clustering of the under-five deaths across the entire study area and identify the variations across the study area by focusing on geographical area and its relationship to nearby areas.

Among the five zones, the North and the East zones have most areas with high proportion of deaths. Parts of the west zone have few places with high proportion of deaths.

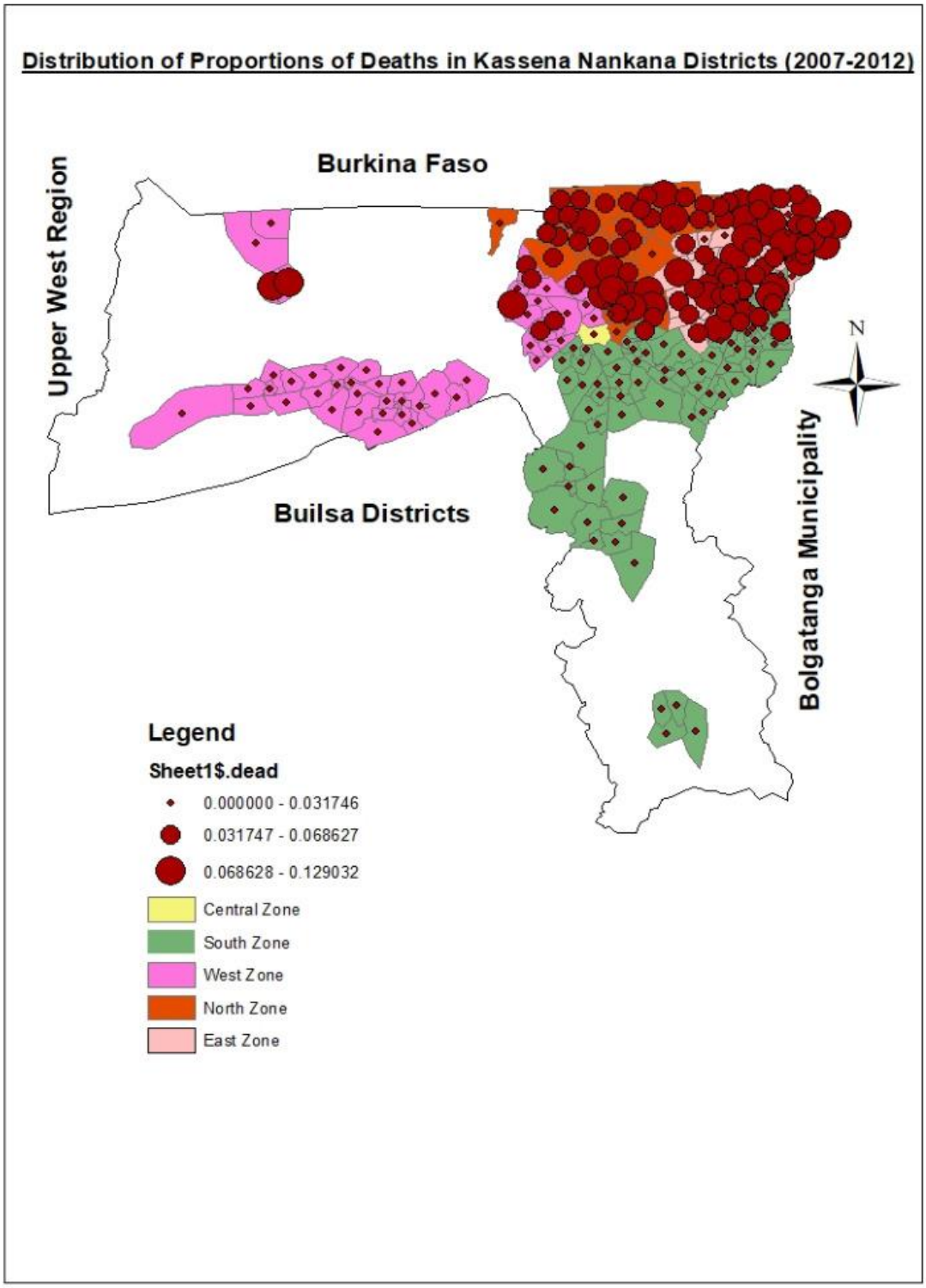
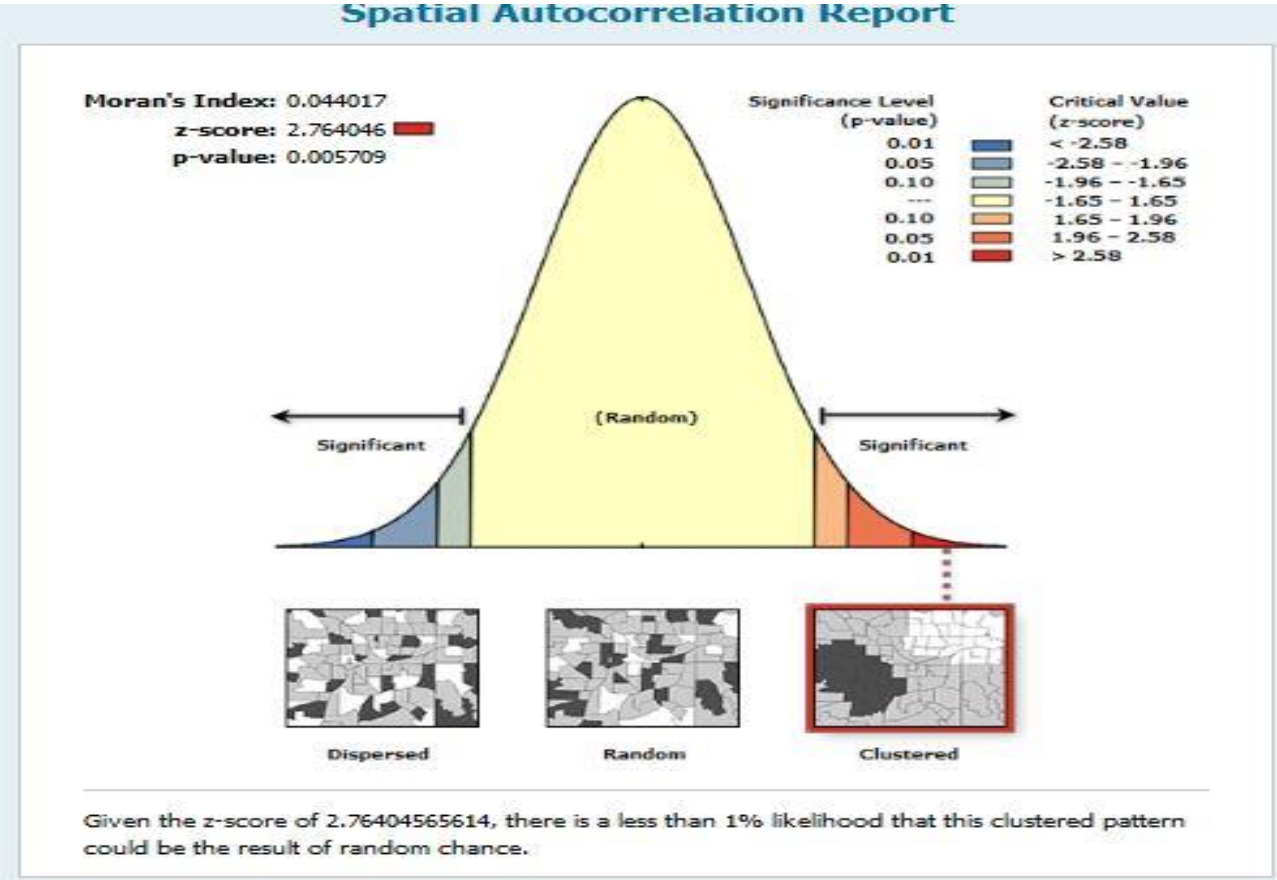


Figure 3. 5: Distribution of Deaths in Kassena-Nankana Districts (2007-2012)

3.4.1 Moran's Index

Figure 3.6 shows results of local Moran's I for under-five mortality. The result of local Moran's I show statistically significant spatial autocorrelation (Moran's I=0.044). The formal test was significant (p=0.005) and, thus we reject the null hypothesis of spatial independence and concluded that there was sufficient evidence of spatial dependence. The Z score (2.76) also point to a clustered pattern.



Global Moran's I Summary

Moran's Index:	0.044017
Expected Index:	-0.004065
Variance:	0.000303
z-score:	2.764046
p-value:	0.005709

Figure 3. 6: showing the Global Moran's Index

*3.4.2 Getis-Ord General G and Getis-Ord Gi**

The local Moran's I identify local clusters and outliers but does not measure the degree of clustering; hence hot spot analysis (Getis-ord Gi* statistics) was also adopted.

Figure 3.7 shows the degree of clustering of under-five mortality in Kassena-Nankana districts. The clusters with red dots belong to the hot spot zones.

Statistically significant hotspots were identified in the North and West zones. Within the North zone, these sections (Chania, Sakaa/Bayono and Gwari) under Paga were identified as being statistically significant hot spots at a 99% confidence level signifying the maximum spatial clustering of high under-five mortality. Statistically significant hot spots were also identified in Baliu, Kadania/Kaninia, Saboro/Akania and Wombio under Kayoro/Wuru village at 99% confidence level signifying the maximum spatial clustering of the under-five mortality in the west zone.

Abuguzio Doone, Gonum/Wolingo from the East zone and Upper Nangalikinia, Tankuna and Janania from the South-east zone were identified as statistically significant cold spots at 99% confidence level indicating the maximum spatial clustering of low under-five death in Kassena-Nankana East and West districts.

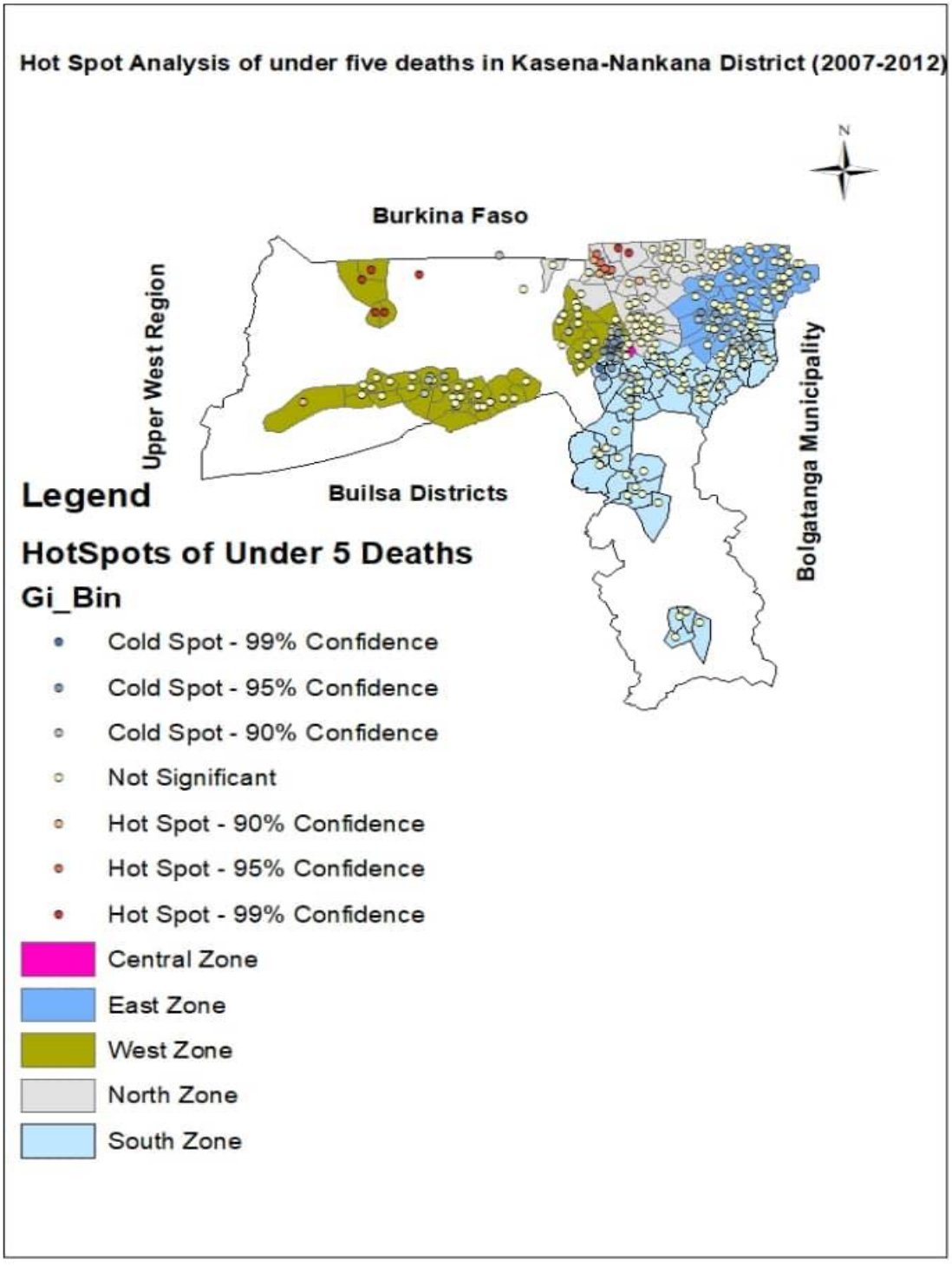


Figure 3. 7: Hot spot analysis of under-five deaths in Kassena-Nankana districts (2007-2012)

3.5 Risk factors associated with under-five mortality

The results of the univariate and multivariable analysis to investigate the risk factors associated with under-five mortality are presented in Table 3.7 after adjusting for clustering. In the univariate analysis, sex of the child, marital status of the mother, maternal age, religion of mother, SES, mother's educational level and birth place were found to be significantly associated with under-five mortality. The study showed that male children had 18% higher risk of dying than female children (HR=1.18, p=0.008, 95% CI: 1.05, 1.34). Children born to mothers who were not married had 37% increased risk of dying before their fifth birthday compared to children whose mothers were married (HR=1.37, p<0.001, 95% CI: 1.18, 1.59). Furthermore, maternal age was significantly associated with under-five mortality. Children to mothers aged 20-34 at the time of their birth had 23% reduced risk of dying before their fifth birthday compared to children to mothers aged <20 years (HR=0.77, p=0.007, 95%CI: 0.63, 0.93). There was no statistically significant difference in under-five mortality between children born to women in the age group of 35 years and above and those aged <20 years (HR=1.02, p=0.834, 95% CI: 0.83, 1.26).

In addition, the hazard ratio for children in Christian households was 0.77 (0.67-0.88) compared to children in households with traditional belief. In the unadjusted model, children in the fourth quintile had a reduced risk of dying (0.71 (0.59-0.87)) compared to children in the first quintile (poorest). Similarly, children in the least poor quintile survived better than children in the poorest quintile (HR=0.59, p=0.002, 95% CI: 0.42, 0.83).

Moreover, children to mothers with secondary or tertiary level education had a reduced risk of under-five death when compared to children to women with no education (HR=0.60, p<0.001,

95% CI: 0.47, 0.78). Also, the HR for children who were delivered at home compared with those delivered at the health facilities was 1.41 (HR=1.41, P<0.001, 95% CI: 1.23, 1.61).

Results from the adjusted hazard model showed sex of child, marital status of the mother, maternal age, religion of mother, SES and birth place were significantly associated with under-five deaths in the study area. Adjusting for other confounding variables, the hazard ratio for being a male compared to a female was 1.20 (HR=1.20, p=0.004, 95% CI: 1.06, 1.36). Marital status of the mother was significantly associated with under-five mortality. Children born to women who were not married had increased under-five mortality than children to women who were married, after adjusting for sex of child, mother's age, religion SES, education level of the mother and place of birth (HR=1.37, p<0.001, 95% CI: 1.18, 1.59). Furthermore, maternal age was associated with under-five mortality with children born to mothers who were aged 20-34 years having 19% reduction in under five mortality compared to children born to mothers who were less than 20 years old, and this was statistically significant after adjusting for other covariates (HR=0.81, p=0.034, 95% CI: 0.67, 0.98). Children from the poorest households were more likely to die before their fifth birthday compared to those from the richest households, after controlling for other covariates (HR=0.72, p=0.028, 95% CI: 0.54, 0.96). The higher the level of education of a child's mother, the less likely the child would die compared to other children to mothers with no education. The hazard ratio for children to mothers with secondary school and above level of education compared to children to mothers who never had formal education was 0.79 (HR=0.79, p=0.078, 95% CI: 0.61, 1.03). The hazard of death for a child whose place of birth was at home was 1.29 times higher the hazard of death for a child whose place of birth was at the health facilities. This showed an increased hazard of death of about 29% for a child born at home compared to a child born at the health facility and this was significant (HR=1.29, p<0.001, 95% CI: 1.12, 1.48) after

adjusting for other covariates. The global test for the factors associated with under-five children within the NHDSS proved that the proportional hazards model assumptions were not violated (p= 0.1756).

A similar analysis was conducted for the different risk factors associated with under-five mortality ignoring clustering of the deaths in different clusters, and the findings were similar except in residence variable which was significant (Appendix B).

Table 3.7: Risk factors associated with under-five deaths by background characteristics of children in Navrongo: 2007-2012

Variables	Unadjusted HR (95%CI)	P-value	Adjusted HR (95%CI)	P-value
Sex of child				
Female	1		1	
Male	1.18 (1.05-1.34)	**0.008**	1.20 (1.06-1.36)	**0.004**
Marital status of mother				
Married	1		1	
Not married	1.37 (1.18-1.59)	**<0.001**	1.37 (1.18-1.59)	**<0.001**
Maternal age				
<=19	1		1	
20-34	0.77 (0.63-0.93)	**0.007**	0.81 (0.67-0.98)	**0.034**
35+	1.02 (0.83-1.26)	0.834	0.98 (0.79-1.22)	0.859
Religion of mother				
Traditional	1		1	
Christianity	0.77 (0.67-0.88)	< 0.001	0.87 (0.75-1.00)	0.049
Islam	0.97 (0.74-1.27)	0.812	1.27 (0.98-1.66)	0.068
Other	0.38 (0.05-2.65)	0.327	0.45 (0.06-3.18)	0.423
Wealth quintile				
Poorest	1		1	
Poorer	0.87 (0.73-1.03)	0.1	0.87 (0.74-1.03)	0.114
Poor	0.92 (0.77-1.09)	0.338	0.93 (0.78-1.11)	0.409
Less poor	0.71 (0.59-0.87)	**0.001**	0.79 (0.65-0.95)	**0.013**
Least poor	0.59 (0.42-0.83)	**0.002**	0.72 (0.54-0.96)	**0.028**
Maternal education				
No education	1		1	
Primary/JSS	0.90 (0.78-1.03)	0.127	0.98 (0.85-1.13)	0.789
Secondary/tertiary	0.60 (0.47-0.78)	**<0.001**	0.79 (0.61-1.03)	0.078

Birth Place				
Health Facility	1		1	
Home/Somewhere	1.41 (1.23-1.61)	<**0.001**	1.29 (1.12-1.48)	<**0.001**

3.5.1 Risk Factors associated with Cause Specific Deaths

An independent association between under-five cause-specific mortality and socio demographic characteristics such as birth order of child, sex of child, marital status of mother, ethnicity of mother, maternal age, religion of mother, residence of mother, SES, mother's education level, birth place and Twinning status was investigated using cox proportional hazard models. The independent models were fitted for each explanatory variable for the follow up period to assess their significance as risk factors for under-five cause-specific mortality. Tables 3.8, 3.9 and 3.10 shows the results of the univariate and multivariable analysis of the factors associated with under-five deaths from communicable, non-communicable and accident/injuries causes respectively in the NHDSS from 2007-2012.

3.5.2 Risk factors associated with under-five deaths from communicable diseases

Table 3.8 shows the risk factors associated with under-five deaths from communicable diseases in the study area from 2007 to 2012. In the univariate analysis, marital status, maternal age, religion, SES, mother's educational level and birth place were found to be associated with under five deaths from communicable diseases.

The study showed that children whose mothers were not married were 1.36 times more likely to die from communicable diseases compared to children whose mothers were married (HR=1.36, p=0.001, 95% CI: 1.14, 1.63). The hazard ratio for dying from a communicable disease for children born to mothers who were aged 20-34 years compared to children born to mothers less than 20 years old was 0.76 (HR=0.76, p=0.027, 95% CI: 0.59, 0.97). There was no difference in dying

from communicable diseases between children to mothers aged 35 years and above and children to mothers aged below 20 years (HR=1.01, p=0.949, 95% CI: 0.77, 1.32).

Under-five children in Christian households had a lower hazard of dying from communicable diseases compared to those in households which practice traditional religion (HR=0.77, p=0.031, 95% CI: 0.65, 0.91). In addition, wealth index was significantly associated with deaths from communicable diseases. Children in less poor and least poor wealth quintiles had significant reduced risk of dying from communicable diseases compared to those in the poorest quintiles [(HR=0.61, p<0.001, 95% CI: 0.47, 0.78) and (HR=0.53, p<0.001, 95% CI: 0.35, 0.81) respectively].

Furthermore, children born to mothers with secondary or higher education were less likely to die from communicable diseases compared to children whose mothers had no formal education (HR=0.47, p<0.001, 95% CI: 0.33, 0.61).

Children delivered at home had a hazard ratio of 1.52 (HR=1.52, p<0.001, 95% CI: 1.29, 1.78) compared to those who were delivered at a health facility of dying from a communicable disease, and this was statistically significant.

Results from the multivariable hazard model (adjusted model) showed that marital status, SES, educational level of mother and birth place were significantly associated with dying from communicable causes for under-five children in the study area. Children under-five years whose mothers were not married had increased risk of dying from communicable diseases compared with children whose mothers were married after adjusting for other covariates (HR=1.37, p<0.001, 95% CI: 1.14, 1.64). Children in the fourth wealth quintile (less poor) had significant reduction in under-five mortality due to communicable diseases when compared to children in the poorest quintile

after adjusting for other confounders in the model (HR=0.70, p=0.005, 95% CI: 0.54, 0.90). Under-five children to mothers with secondary or tertiary education had a 39% reduced risk of dying from a communicable disease when compared with children to mothers with no formal education, after controlling for other confounding variables (HR=0.61, p=0.005, 95% CI: 0.44, 0.86). Similarly, children delivered at home had a 33% increased risk of dying from communicable cause (HR=1.33, p=0.001, 95% CI: 1.12, 1.58) compared to children delivered at health facilities. Assessment of the overall model showed the proportional hazard assumptions were not violated (p= 0.7023).

Table 3. 8: Background characteristics and associated under-five deaths from communicable diseases in Navrongo HDSS, 2007-2012

Variables	Unadjusted HR (95%CI)	P-value	Adjusted HR (95%CI)	P-value
Sex of child				
Female	1			
Male	1.04 (0.88-1.22)	0.634		
Marital status of mother				
Married	1		1	
Not married	1.36 (1.14-1.63)	**0.001**	1.37 (1.14-1.64)	**<0.001**
Maternal age				
<=19	1		1	
20-34	0.76 (0.59-0.97)	**0.027**	0.80 (0.62-1.02)	0.070
35+	1.01 (0.77-1.32)	0.949	0.92 (0.70-1.22)	0.579
Religion of mother				
Traditional	1		1	
Christianity	0.77 (0.65-0.91)	**0.003**	0.9 (0.76-1.08)	0.269
Islam	0.86 (0.61-1.19)	0.361	1.19 (0.86-1.66)	0.294
Other				
Wealth quintile				
Poorest	1		1	
Poorer	0.9 (0.72-1.11)	0.317	0.90 (0.73-1.12)	0.342
poor	0.83 (0.67-1.03)	0.109	0.84 (0.68-1.04)	0.106
Less poor	0.61 (0.47-0.78)	**<0.001**	0.70 (0.54-0.90)	**0.005**
Least poor	0.53 (0.35-0.81)	**<0.001**	0.73 (0.50-1.08)	0.119
Maternal education				

No education	1		1	
Primary/JSS	0.86 (0.71-1.03)	0.092	0.93 (0.77-1.13)	0.478
Secondary/tertiary	0.47 (0.33-0.66)	**<0.001**	0.61 (0.44-0.86)	**0.005**
Birth Place				
Health Facility	1		1	
Home/Somewhere	1.52 (1.29-1.78)	**<0.001**	1.33 (1.12-1.58)	**0.001**

3.5.3 Risk Factors associated with Non-Communicable Cause of Deaths

Table 3.9 shows the results of the univariate and multivariable analysis of the factors associated with non-communicable causes of under-five deaths. The study showed that children who were born to women who were not married were 1.4 times more likely to die from non-communicable causes compared to children who were born to women who were married. This was statistically significant (HR= 1.39, p=0.045, 95% CI: 1.01, 1.90). Maternal age was also found to be associated with non-communicable causes of death among under-five children. Children born to mothers aged 20-34 years had a reduced hazard of dying from non-communicable causes by 31% compared to children born to mothers aged less than 20 years when they were born (HR=0.69, p=0.081, 95% CI: 0.45, 1.05). Furthermore, the results on religious beliefs showed that a Christian had a 32% reduced risk of dying from non-communicable diseases compared to a traditional believer (HR=0.68, p=0.05, 95% CI: 0.50, 0.92), and this was statistically significant.

In the multivariable analysis (adjusted model), marital status and religion of mother were found to be statistically significantly associated with non-communicable causes of death in the study area. Children whose mothers were not married after adjusting for maternal age and religion had a higher risk of dying from non-communicable diseases with hazard ratio of 1.35 relative to children whose mothers were married (HR=1.35, p=0.067, 95% CI:0.98, 1.85). Religious beliefs did show significant association with non-communicable cause for under-five mortality after controlling for other covariates. Being a Christian was associated with a reduced risk of dying from non-

communicable diseases among under-five children compared to being a traditionalist (HR=0.69, p=0.015, 95% CI: 0.51, 0.93)

The global test showed that the proportional hazards model assumptions were not violated (*p*=0.389).

Table 3. 9: The association between background factors and under-five deaths from Non-Communicable diseases in the Navrongo Health Demographic Surveillance System, 2007-2012

Variables	Unadjusted HR (95%CI	P-value	Adjusted HR (95%CI)	P-value
Marital status of mother				
Married	1		1	
Not married	1.39(1.01-1.90)	**0.045**	1.35 (0.98-1.85)	**0.067**
Maternal age				
<=19	1		1	
20-34	0.69(0.45-1.05)	0.081	0.73(0.48-1.11)	0.142
35+	1.04(0.68-1.61)	0.848	1.08 (0.70-1.66)	0.740
Religion of mother				
Traditional	1		1	
Christianity	0.68(0.50-0.92)	**0.011**	0.69 (0.51-0.93)	**0.015**
Islam	1.07(0.66-1.73)	0.779	1.27 (0.76-2.11)	0.356
Other				

3.5.4 Risk Factors associated with under-five deaths from Accident/Injuries

Table 3.10 shows the results of the univariate and multivariable analysis of the socio demographic factors associated with under-five deaths from accident/injury causes. The results showed that religion, education level of the mother and twinning status some of the factors associated with deaths due to accident/injury in bivariate analysis.

Children who were Christians had a statistically significant reduction in the risk of dying from accidents/injuries (HR=0.63, p=0.046, 95% CI: 0.39, 0.99) compared to children who were

traditional believers. Children who practiced Islam had a non-significant 5% increase in the hazard of dying from accidents or injuries (HR=1.05, p=0.890, 95% CI: 0.49, 1.81) compared to children who were traditional believers.

Maternal education was not associated with under-five deaths due to accident/injury. Under-five children mothers with secondary or tertiary education were less likely to die from accident/injury. The study showed that children mothers with primary/junior high school level education had a hazard ratio of 1.10 (HR=1.10, p=0.660, 95% CI: 071, 1.71) of dying from an accident/injury cause compared to those who had never attended school. The hazard ratio for children born to mothers with secondary or tertiary level education compared to children born to mothers who never attended school was 0.48 (HR=0.48, p=0.070, 95% CI: 0.22, 1.06). The study further showed that multiple birth were 6.73 times more likely to die from accident/injury than singleton birth (HR=6.73, p<0.001, 95% CI: 3.84, 11.79), and this was statistically significant.

In the multivariable cox proportional hazard model (adjusted model), twinning type was the only factor found to be significantly associated with accident/injury cause of under-five deaths. Multiple birth children were 6.98 times more likely to die before the age of 5 from accident/injury compared to singleton birth (HR=6.98, p<0.001, 95% CI: 3.97, 12.30) after adjusting for religion and education level of the mother. Children whose mothers attained a secondary or tertiary level education had a 48% reduced risk of death from accident/injury cause compared to children whose mothers did not attend formal school (HR=0.52, p<0.001, 95% CI: 0.23, 1.16).

The proportional hazard assumptions were investigated and were not violated with a global test of p= 0.176.

Table 3. 10: Univariate and Multivariable Analysis of the factors associated with under-five deaths from Accidents/Injuries in the Navrongo Health Demographic Surveillance System, 2007-2012

Variables	Unadjusted HR (95%CI)	P-value	Adjusted HR (95%CI)	P-value
Religion of mother				
Traditional	1		1	
Christianity	0.63(0.39-0.99)	0.046	0.66(0.41-1.06)	0.085
Islam	1.05(0.53-2.10)	0.890	1.15(0.58-2.29)	0.693
Other	-	-	-	-
Maternal education				
No education	1		1	
Primary/JSS	1.10(0.71-1.71)	0.680	1.18(0.75-1.86)	0.472
Secondary/tertiary	0.48(0.22-1.06)	0.070	0.52(0.23-1.16)	0.108
Twinning status				
Singleton	1		1	
Multiple	6.73(3.84-11.79)	**<0.001**	6.98(3.97-12.3)	**<0.001**

Multinomial logistic regression showing the risk factors on Non-communicable and Accident/injuries verses communicable

Table 3.11 shows the relationship between socio demographic factors and broader categories of deaths. Multinomial logistic regression analyses were applied to assess the effect of selected variables on non-communicable diseases and accident/injuries over communicable diseases. The model included variables such as sex of child, marital status of the mother, maternal age, religion, socio-economic status of the household and birth place. After adjusting for other factors, the model showed that marital status of the mother, maternal age, religion, socioeconomic status of the household had no significant effect accident/injuries over communicable diseases.

Mother's education showed no relationship with non-communicable over communicable causes of death. For instance, as compared to the children whose mothers had higher education, the children whose mothers had primary/JSS level of education and no formal education were 57% and 65% less likely to die from non-communicable causes over communicable causes compared

to children whose mothers who had secondary level education or above (RRR=0.43, p<0.001, 95% CI: 0.25, 0.72) and (RRR=0.35, p<0.001, 95% CI: 0.19, 0.63) respectively. However, mother's education was not a significant factor for accident/injuries cause over communicable causes of deaths.

The child's sex and place of birth were found to have significant effect on accident/injuries deaths. The multivariable analysis showed that, male children were 1.65 times more likely to die from accident/injuries over communicable conditions compared to female children (RRR=1.65, p=0.014, 95% CI: 1.10, 2.47). This was not significant for non-communicable cause over communicable cause.

Children delivered at health facilities were 1.54 times more likely to die from accident/injuries over communicable diseases than children who were delivered at home or elsewhere (RRR=1.54, p=0.048, 95% CI: 1.00, 2.36).

Table 3. 11: Multinomial logistic regression showing the risk factors on Non-communicable and Accident/injuries verses communicable

Variables	Non-Communicable vs Communicable	P-value	Accident/Injuries vs Communicable	P-value
Sex of child				
Female	1		1	
Male	1.19 (0.86-1.64)	0.297	1.65 (1.10-2.47)	**0.014**
Marital status of mother				
Married	1		1	
Not married	1.07 (0.74-1.53)	0.713	0.77 (0.48-1.22)	0.27
Maternal age				
<=19	1		1	
20-34	0.79 (0.55-1.47)	0.668	0.91 (0.51-1.64)	0.755
35+	1.17 (0.60-2.28)	0.686	0.99 (0.50-1.93)	0.967
Religion of mother				
Traditional	1		1	
Christianity	0.79 (0.56-1.12)	0.179	1.01 (0.66-1.54)	0.961
Islam	1.17 (0.60-2.28)	0.654	1.28(0.57-2.87)	0.554
Wealth quintile				
Poorest	1		1	
Poorer	0.81 (0.51-1.27)	0.35	0.95 (0.57-1.61)	0.862
poor	1.35 (0.86-2.13)	0.191	1.18 (0.67-2.07)	0.562
Less poor	1.45 (0.88-2.38)	0.145	1.14 (0.61-2.11)	0.682
Least poor	0.90 (0.42-1.93)	0.791	0.77 (0.30-2.00)	0.594
Maternal education				
Secondary/tertiary	1		1	
No education	0.35 (0.19-0.63)	**<0.001**	1.00 (0.46-2.53)	0.862
Primary/JSS	0.43 (0.25-0.72)	**<0.001**	0.93 (0.40-2.18)	0.686
Birth Place				
Home/Somewhere	1		1	
Health Facility	0.88 (0.62-1.24)	0.454	1.54 (1.00-2.36)	**0.048**

CHAPTER 4: DISCUSSION AND CONCLUSION

The focus of this study was to use longitudinal data to estimate under-five mortality rates, identify risk factors associated with causes of under-five deaths over a six years period of follow-up in northern Ghana. The study determined socio demographic risk factors for under-five deaths as well as factors associated with the broad causes of under-five deaths. This chapter therefore presents a comprehensive discussion and conclusion on the findings of the study.

4.1 Causes of Under-five Deaths

Of the 20,651 under-five children that were followed over the six years period, 1010 deaths were reported out of which 963 were assigned causes of death through verbal autopsy.

This study identified neonatal pneumonia as the leading cause of death among neonates, followed by prematurity and birth asphyxia. Also, the results from this study showed that birth asphyxia was the leading cause of death among early neonates in the study area, and this is comparable to what was found in a study by Adebami et al (2010) (74) in Nigeria. It has also been demonstrated in a multicentre prospective study involving 4267 participants in east, central and southern Africa that birth asphyxia was the top cause of death among early newly borns (75).

In contrast to the findings that pneumonia is the leading cause of neonatal deaths, another study conducted in the same area from 1998 to 2002 showed that birth asphyxia contributed most to the causes of neonatal deaths in the area (59). The inconsistency could be attributed to differences in study design and period of study. While preterm related issues are the dominant causes of neonatal deaths in South Asia (75), the causes of neonatal deaths in Sub-Saharan Africa are dominated by pneumonia (76).

The results of this study show malaria still remains the leading cause of death among under-five children in the study area. About 19% of the 963 deaths were attributed to malaria. In a study conducted in the same area, malaria was the cause of most of the under-five deaths (77). Other studies in other parts of rural Ghana have shown that malaria was the leading cause of deaths among under-five children (78).

In some other African countries, 17% of under-five deaths were due to malaria (79), and this is comparable to what we found in our study. The results from this study shows the importance of malaria as a leading cause of death among under-five children in Sub-Saharan African areas and the findings are comparable to what was found by Adjuik et al (79).

The study found that majority of children aged 1-4 years died from malaria. The high proportion of deaths from malaria is largely due to the study area being a high malaria transmission area. There is an increase in vector breeding, particularly in the raining season and this leads to an upsurge in malaria cases and deaths and supports an earlier transmission study (80). Regular use of insecticide treated nets (ITNs) will help reduce the burden of malaria cases and malaria deaths as some studies have shown that children under-five who do not use ITNs having higher incidence of severe anaemic and cerebral malaria compared to those who use ITNs (80).

Communicable diseases accounted for 40% of the deaths among children under five. Babayara et al (2018) found in a cross-sectional study in Northern Ghana that communicable disease accounted for 54 percent and was the main cause of child mortality (77).

4.2 Risk factors of under-five mortality

In our study, we found that children to young women below 20 years were associated with increased risk of under-five death compared to children born to mothers aged 20 to 35 years. Our

study results are consistent with other findings from many previous studies as younger women < 20 years were associated with increased risk of under-five death compared to children born to mothers aged 20 to 35 years (81–83). This could be attributed to under developed uterus. We did not find any statistically significant difference in the risk of dying between children born to mothers below 20 years, and those born to mothers aged 35 years or more. However, another study in northern Ghana found that children born to women aged 35 years and above were more likely to experience an under-five death compared to women below 20 years of age (84). Other studies have identified maternal age as a strong predictor of child survival (85).

The findings from this study showed that children in rural areas were more at risk of dying before age 5 compared to those in urban areas. A study in China suggested that neonatal health is poor in rural areas compared to urban areas (85). A study in Kenya indicated that child mortality was more likely to be experienced in rural settings compared to urban areas (86). Some authors concluded that the rural-urban disparity in child mortality was of critical concern in Ghana and sub-Saharan Africa (87).

The results from our study showed that socioeconomic status is significantly associated with child survival. Specifically, the results showed that children in the poorest wealth quantile have higher risks of experiencing mortality compared to those in the higher wealth quintiles. Differences in socioeconomic status has an effect on child survival as evidence suggests that poor families are less likely to have adequate access to healthcare (88). In line with this, literature suggests that children from poor homes are at risk of getting infected by pathogens and are likely to die as a result of limited access to life saving medicines (89).

The evidence from this study adds up to the growing evidence (over the years) to indicate that the poor is at a higher risk of experiencing child mortality (90). As such, targeting under-five child mortality interventions would be well premised. Interventions should include improving access to adequate and quality healthcare to the poor (health facilities, human resource and logistics) as well as implementing poverty alleviation policies (91).

Results from our study showed that education level of the mother is associated with the risk of experiencing an under-five death. Specifically, we realized that mothers of higher education level were less likely to experience an under-five death as compared to those with no formal education. Similarly, a study in Zimbabwe found that maternal education was a predictor of child health as mothers education was protective against child mortality (92). This is consistent with another similar study in Turkey which found that, maternal education improves child survival by improving maternal and reproductive lifestyles (92).

Results from our study showed gender difference in child survival as under-five mortality was higher in male than female children. Evidence as stated in a UN report (on sex differentials in childhood mortality) shows that more countries report higher mortality rates in males than females (95). This was largely attributed to natural anatomy. With a few exceptions like China and India, girls have no advantage over boys in child mortality (93).

4.3 Communicable disease deaths and predictors

A high proportion of the broad cause of deaths was due to communicable diseases, and most of them were due to malaria and a pneumonia. A study in rural Cameroon found that deaths due to communicable diseases accounted for the highest proportion of under-five deaths, and 17.5% were due to malaria, the most common cause of death among children under-five years (43).

Similarly to our study another study conducted in the Kasena-Nankana district showed that, malaria was the leading cause of death among children under five (77). This is consistent with evidence suggesting that, malaria and pneumonia remain the leading causes of under-five deaths in the sub-Saharan Africa region (94). Evidence from our study as well as the growing amount of evidence from literature would therefore imply that, interventions should be targeted at addressing the main causes of child deaths to reduce overall child mortality.

Our study area is mainly rural and we found sex, age, marital status, SES and birth place to be significantly associated with under five deaths from communicable diseases. Children to women who were not married had increased risk of dying before age 5 compared to children to women who were married. Consistent with these findings, Yaya et al (2018), who conducted a study to assess under five mortality patterns and associated maternal risk factors in sub-Saharan Africa found that lack of spousal support (not currently married) resulted to increase in under-five mortality (DR Congo- HR = 1.24, 95%CI = 1.11-1.40; Mali- HR = 2.43, 95%CI = 1.63-3.64; Niger- HR = 1.59, 95%CI = 1.24-2.03; Zimbabwe- HR = 1.33, 95%CI = 1.06-1.67) (95). Reasons could be that most unmarried women with children lack the financial capacity to provide good healthcare for their children including early healthcare seeking. As a result, this could increase the risk of dying for children of mothers.

The present study also found that maternal age 20-34 years was associated with reduced risk of under-five mortality. Children born to mothers who were aged 20-34 years had 19% reduction in under five mortality compared to children born to mothers who were less than 20 years old, and this was statistically significant after adjusting for other covariates. This finding is in contrast with a cohort study by Sinha et al (2017) in Delhi. Sinha et al found that older (≥35 years) maternal ages were associated with a higher risk of offspring mortality (HR=1.68; 95% CI: 1.16-2.43) (96).

Nonetheless, this study also found that children from the poorest households were more likely to die before their fifth birthday than those from the richest households after controlling for other covariates. This is in line with a study done by Stringhini et al (2017) where participants with low socioeconomic status had higher mortality compared with those with high socioeconomic status (HR 1·42, 95% CI 1·38–1·45) (97).

Our study shows that children born to mothers with secondary or higher education have reduced risk of dying from communicable diseases compared to children born to mothers with no formal education. Our findings are consistent with a study in Malawi which showed that, higher maternal education significantly improved child survival (98).

In addition, our study found that children delivered at home had a 33% increased risk of dying from communicable diseases compared to children delivered at health facilities. Similar findings have been elucidated in studies in Nigeria by Adewale (2002) (99) and Indonesia by Titaley et al (2012) (100).

4.4 Non-communicable disease deaths and predictors

Findings from our study indicates that among those who died from non-communicable causes, most of them were due to prematurity (43%) and congenital malformation (14%). Also, being a Christian was associated with a reduced risk of dying from non-communicable diseases among under-five children compared to being a traditionalist (HR=0.69, p=0.015, 95% CI: 0.51, 0.93). Fewer studies have been done with regards to non-communicable disease deaths among under five children. However, a study in Mozambique by Cau et al (2013) did not find any statistically significant difference in the risk of dying by religion (101).

4.5 Predictors of non-communicable and accident/injuries over communicable disease deaths

Multinomial logistic regression analyses were done to assess the effect of selected variables on deaths due to non-communicable diseases and accident/injuries over communicable diseases.

Our results show that children whose mothers had primary/JSS level of education and no formal education were 57% and 65% less likely to die from non-communicable causes over communicable causes than children whose mother's educational level was secondary and above . This could imply that children to mothers with primary/JSS level of education and no formal education are more likely to die from communicable diseases than children whose mother's educational level was secondary or above. Possible reasons could be attributed to inadequate knowledge and practice among mothers with primary/JSS level of education and no formal education on the prevention and control measures of communicable diseases such as the childhood vaccine preventable diseases.

4.6 Strengths of the study

This study used longitudinal data from a Health and Demographic Health Surveillance System (HDSS) site. HDSS ensures the use of standardized questionnaires for the data collection. The data were collected by experienced data collectors and data collection is supervised. Response rate to HDSS data collection is relatively high (97.0%) (102). This study leverages much on the use of standardized questionnaires and approaches in a known HDSS site and therefore makes the data comparable across different DHSS sites in different countries. The quality of data is good and data from the HDSS have been used by many international and national organization for the impact evaluation of health interventions.

4.7 Limitations of the study

This study could not draw a causal relationship because it is based on retrospective longitudinal data. Though HDSS data collection is done by properly trained workers to ensure accuracy of data, some mothers may have not reported all births, especially if the child died immediately after birth. Also, because of hidden and unmeasured confounders, there is a possibility of residual confounding. Again, secondary data from the NDSS does not include health system factors variables hence was not included in the analysis.

4.8 Future research

This study was specifically conducted in two districts (Kassena-Nankana East and West) of the Upper East region which differ in context as compared to other regions of Ghana. Due to contextual differences such as access to healthcare and socio-demographic settings across regions, conducting a similar study in other parts of the country could also reveal interesting results. This will provide more evidence for countrywide policy making. This study only focused on socio-demographic factors. It would therefore be interesting for studies to be conducted to explore other factors.

4.9 Conclusion and recommendation

This study focused on studying the causes and risk factors associated with under-five mortality in Northern Ghana. The study shows that under-five mortality rates in the study area remains relatively high across clusters with marginal differences. Maternal age of less than 20 years, low socio-economic status of mother, being male, being a single mother, mother with no formal education and delivery at home were significantly associated with increased risk of under-five deaths in the study area.

Education level of the mother is important for improving child survival as realized in the results of this study and other similar studies. It would be therefore well premised to put in place interventions to improve on formal education among women of reproductive age. Though long-term interventions such as formal education in schools already exists, short term community-based interventions to educate women on maternity and child bearing could help improve child survival.

Multiple risk factors on child mortality as identified in this study requires multi-pronged approaches including health interventions to improve child survival. In the case of the Kassena-Nankana districts, specific interventions should be targeted at addressing the risk factors identified in this study. To achieve the sustainable development goal of reducing child mortality, sub-Saharan countries would need to prioritize the health of children and mothers.

Malaria and pneumonia are the leading causes of under-five deaths in the study area. Ending preventable deaths of children worldwide will require targeted interventions to reduce the major causes of death among under five children.

The study further recommends that as a developing country, Ghana needs to conduct studies that will help it appropriately target the poor before implementing the various pro-poor programs.

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APPENDICES

Appendix A: Proportion of Broad Causes of Deaths by Age in Navrongo Health Demographic Surveillance System, 2007-2012

Overall		Age at death		
		0-27days	1-11moths	1-4years
Causes	Total	n(%)	n(%)	n(%)
Communicable	604	105(17.4)	247(40.9)	252(41.7)
Non-communicable	185	134(72.4)	34(18.4)	17(9.2)
Accident/Injuries	97	70(72.2)	8(8.2)	19(19.6)
Malnutrition	25	0(0.0)	12(48.0)	13(52.0)
Undetermined	52	1(1.9)	21(40.4)	30(57.7)
Total	963	310(32.2)	322(33.4)	331(34.4)

X^2 =308.814, p-value<0.001

Appendix B: Risk factors associated with under-five deaths by background characteristics of children in Navrongo: 2007-2012

Variables	Unadjusted HR (95%CI)	P-value	Adjusted HR (95%CI)	P-value
Sex of child				
Female	1		1	
Male	1.18 (1.05-1.34)	0.007	1.20 (1.06-1.36)	0.004
Marital status of mother				
Married	Ref		1	
Not married	1.37 (1.2-1.57)	<0.001	1.36 (1.18-1.56)	<0.001
Maternal age				
<=19	1		1	
20-34	0.77 (0.64-0.93)	0.007	0.88 (0.71-1.10)	0.265
35+	1.02 (0.83-1.26)	0.832	1.05 (0.80-1.40)	0.71
Religion				
Traditional	1		1	
Christianity	0.77 (0.68-0.88)	< 0.001	0.75 (0.64-0.89)	0.001
Islam	0.97 (0.76-1.23)	0.788	0.97 (0.76-1.23)	0.788
Other	0.38 (0.05-2.68)	0.329	0.38 (0.05-2.68)	0.329
Residence				
Urban	1		1	
Rural	1.29 (1.06-1.58)	0.013	0.96 (0.75-1.24)	0.777
Wealth quintile				
Poorest	1		1	
Poorer	0.87 (0.74-1.03)	0.097	0.87 (0.74-1.03)	0.108
poor	0.92 (0.77-1.09)	0.337	0.93 (0.78-1.11)	0.403
Less poor	0.71 (0.59-0.86)	0.001	0.78 (0.64-0.96)	0.018
Least poor	0.59 (0.46-0.75)	< 0.001	0.70 (0.51-0.96)	0.029
Maternal education				
No education	1		1	
Primary/JSS	0.9 (0.78-1.03)	0.112	0.98 (0.85-1.13)	0.796
Secondary/tertiary	0.6 (0.48-0.75)	<0.001	0.78 (0.60-1.00)	0.047
Birth Place				
Health Facility	1		1	
Home/Somewhere	1.41 (1.24-1.59)	<0.001	1.3 (1.14-1.49)	<0.001
Birth order of child				
1-	1		1	
2-4	0.87 (0.75-1.01)	0.067	0.86 (0.72-1.02)	0.077
5+	1.16 (0.98-1.36)	0.085	0.93 (0.73-1.17)	0.512

**The results presented in this table did not adjust for clustering of deaths