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Cause specific under-five mortality rates and associated risk factors among children in northern Ghana between 2007 and 2012 using survival analysis techniques.

Samuel T. Oladokun[1,2*], Paul Welaga[1,3], Engelbert A. Nonterah[1,3,4], Patrick Ansah[1], Abraham Oduro[1,5], Tobias Chirwa[2]

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[1] Navrongo Health Research Centre, Ghana Health Service, Navrongo, Ghana ; s_oladokun@yahoo.com ; drenanonterah@gmail.com ; lonpoa2@gmail.com
[2] School of Public Health, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa ; tobias.chirwa@wits.ac.za
[3] School of Public Health, C.K. Tedam University of Technology and Applied Sciences, Navrongo ; pwelaga@yahoo.com
[4] Julius Global Health, Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht University, Utrecht, the Netherlands ; drenanonterah@gmail.com
[5] Research and Development Division, Ghana Health Service, Headquarters, Accra, Ghana ; aroduro@yahoo.com

* Correspondence: s_oladokun@yahoo.com; Tel. +233 24 384 6453

Abstract: This study assessed the causes of under-five (U5) deaths and examined the associated risk factors in northern Ghana. The study analyzed prospectively collected longitudinal data of children born between 1st January 2007 and 31st December 2012 and resident in the Navrongo Health and Demographic Surveillance System (NHDSS) area in northern Ghana. Data from 20,651 children were analyzed with 1,056 under-five deaths and 51,783 person-years of observation. The overall mortality rate was 19.5 per 1000 person-years of observation. The main cause of under-five deaths was malaria (19.5%). Being male (Hazards ratio [95% CI]; 1.20 [1.06 - 1.36]; p=0.004), children born to single mothers (1.3 [1.18 - 1.59]; p<0.001) and home deliveries (1.29 [1.12 - 1.48]; p<0.001) were associated with increased risk of mortality. Children born to women aged 20-34 years (0.81 [0.67 – 0.98]; p=0.0.25) were associated with relatively lower risk of death compared to those born to women aged 19 years and below. Children from high socioeconomic households had relatively lower risk of death even though not statistically significant (0.87 [0.74 - 1.03]; p=0.056). Malaria remains the leading cause of under-five deaths in the study area. Adherence to prevailing malaria prevention measures including use of insecticide treated bed-nets, seasonal chemo-prophylaxis, indoor-residual spraying and adequate access to healthcare will greatly improve child survival.

Keywords: Under-five mortality; neonatal mortality; verbal autopsy; Northern Ghana and Sustainable Development Goals

1. Introduction

Under-five mortality (U5M) is still a critical challenge globally, especially in Sub Sahara Africa (SSA). The disparities in child mortality between low- and high-income countries continue to be high and persistent (1). Of all the World Health Organization (WHO) regions, the African region has the highest risk of a child dying before attaining the age of five years (76.5 per 1000 live births) (1). The global under-five mortality rate was approximately 38.1 deaths per 1,000 live births in 2021, reflecting a comparison to 1990 (2), but the situation seems to remain the same in SSA including Ghana. Ghana had a 52% decline in U5M from 2000 to 2015 (3). Despite this modest decline, U5M still remains an important health concern to address if we seek to attain targets set in the Sustainable Development Goal (SDG) 3.2. Being a critical indicator for child health and well-being, these disparities may well reflect either persistent inadequacies in the

healthcare system to address the prevailing factors or lack of contextual research to identify important community interventions (4).

The causes of U5M are many and vary across the WHO regions and between countries, emphasizing the need for contextual research to prioritize interventions. The Global Burden of Disease study observed in 2019 that neonatal diseases remained the greatest cause of death among children under the age of five, followed by lower respiratory infections, diarrhoeal diseases, congenital birth defects and malaria (5). Specifically, in South Asia, preterm related problems or complications dominated the 2 million under-five reported deaths. However, in SSA, under-five deaths are predominantly caused by infectious diseases such as pneumonia and malaria. Other causes of U5M in countries with higher rates were attributable to preterm complications while congenital anomalies dominated the causes in countries with low U5M rates (6).

Studies have established that child mortality differs by sex with neonatal mortality reported to be higher among male than female children (7). Within SSA, male babies are highly susceptible to mortality before 5 years (8). Socioeconomic status has also been linked to the risk of U5 mortality with a study in rural Tanzania observing that children from poor homes had limited access to healthcare and were likely to die before five years compared to rich children (9). An analysis of data across 47 countries showed that children born into poor homes were more likely to die compared to their rich counterparts (10).

A study in Northern Ghana revealed that single and widowed women experienced relatively high infant and child mortality rates (11). Some studies observed that the age of the mother at birth and mother's education were also significantly associated with child mortality (12).

As U5M reflect a wide array of interventions such as vaccination or other preventive measures, medical treatment of infectious and other diseases as well as adequate nutrition among others, it is important to generate contextual factors relating these mortalities. This is an important step in generating targeted community appropriate interventions that will help mitigate the high under-five mortality rates in communities within SSA.

This study sets out to assess the causes of under-five deaths and investigate the associated risk factors in the coverage area of the Navrongo Health and Demographic Surveillance System (HDSS) from 1st January 2007 to 31st December 2012 in Northern Ghana.

2. Materials and Methods

Study area

The study was conducted in the two Kassena Nankana districts (West and East) located in the northeastern corner of Ghana and bordering Burkina Faso. 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 for the rest of the months. The area has an annual mean rainfall of approximately 1300 mm with mean monthly temperatures ranging from 22.88°C to 34.48°C (13). Economically, the people in the study area are engaged in petty trading, agriculture, and tourism. The districts constitute the surveillance area of the Navrongo Health and Demographic Surveillance System (NHDSS) which is being managed by the Navrongo Health Research Center (NHRC).

In terms of healthcare delivery, the study area has one secondary referral facility (The Navrongo War Memorial Hospital) (14,15). In addition to the hospital, there are seven health centers, 27 community health and planning services (CHPS) compounds with resident health workers, and several other primary health care clinics (13). The CHPS compounds offer antenatal, postnatal and child welfare services and make use of community health volunteers to deliver essential health services (16).

Study design

The data for the analyses were extracted from the database of the Navrongo Health and Demographic Surveillance System (NHDSS), which routinely collects and updates records of births, deaths, marriages, in- and out-migration, and other socio-demographic data on households and individuals within the coverage area. The current study analysed prospectively collected NHDSS longitudinal data spanning six years from 1st January 2007 to 31st December 2012.

Sample size

In all, 20,651 children under-five years of age born between 1st January 2007 and 31st December 2012 and registered into the NHDSS database, including 1,056 deaths were included in this study.

Data

All children born between 2007 and 2012 in the Demographic and Surveillance Area (DSA) and registered into the database of NHDSS were included in the analyses. Children under-five years born outside the DSA but migrated into the DSA during the study period were excluded from the analyses because most of these in-migrant children had missing values for some key variables required for the analyses.

Measurement of variables

Variables included in the analyses were age of the child, household wealth index, sex of the child, maternal educational status, marital status, maternal age, religion, ethnicity and place of delivery. For the analyses, maternal age was categorized into ≤ 19 years (teen mothers), 20-34 years and ≥35 years (17). We computed household wealth index using principal component analysis (PCA) from 30 separate household items, from large assets (e.g., land and car ownership) to smaller household items (e.g., phone, fan ownership). The principal component analysis of the household assets or items was done to predict factor scores. These scores were then categorized into wealth quintiles: Q1 = poorest, Q2 = poorer, Q3 = poor, Q4 = less poor and Q5 = least poor. Maternal education was self-reported and categorized according to educational levels in the country. These categories included no formal education for those who have never being exposed to formal education, those who completed primary or junior high school and those who completed senior high school or tertiary education. Religion was categorized into the three main religions in the country – traditional, Christian or Islam. Marital status was categorized as married and never married. Place of delivery was defined as either delivered in a health facility (primary to secondary health facility and supervised by a trained health personnel) or delivery at home or other places apart from the formal health facility and not being supervised by a trained health personnel. Ethnicity was self-identification with the three major ethno-linguistic groups; Kasem, Nankam, or Buli.

Verbal autopsy Data

The data used to establish the causes of death were extracted from the verbal autopsy database of the NHDSS. Verbal autopsy is routinely conducted on every death that occurs in the DSA. Verbal autopsy is an epidemiological tool that is used to assess causes of death in populations where data on causes of death are lacking. Experienced field supervisors carry out structured interviews with close relatives or the main caregiver of the deceased before death. A suit of computer models (InterVA4) was used to assign probable causes of death for all under-five children who died during the study period using the verbal autopsy data collected (18).

Data analysis

We used STATA 16.0 for all analyses. Follow-up period was censored on 31st December 2012. Kaplan Meir survival curves were used to depict the overall survival experience of the children during follow-up. The equality of survival experience by background variables was assessed using a log-rank test. Cox proportional hazards models with age as the underlying time and reported as mortality hazard ratios (HRs) with 95% confidence interval (CI) were used to assess the association between baseline sociodemographic characteristics and subsequent mortality. The proportional hazards assumption for the Cox proportional hazard models were checked visually and tested using Schoenfeld residuals, and were found not to be violated. We adjusted for age, wealth index, sex, maternal education, marital status, maternal age, religion and place of delivery. A wealth index was computed from a list of household assets using principal component analysis (PCA).

3. Results

Sociodemographic characteristics

In all, 20,651 children under the age of five years were followed up from January 1, 2007 to December 31, 2012. A near equal number of female (49.9%) and male (50.1%) children were included in this study. The two main ethnic groups were the Kasem (50.6%) and the Nankam (45.0%). Approximately 67% of the mothers were aged 20 to 34 years with majority of the mothers (75.7%) being married. Christianity (50.4%) and traditionalists (42.1%) were the dominant

religious groups and 86.6% of the participants resided in rural parts of the study area. Nearly 30% of households were in the less and least poor wealth quintiles (Table 1).

Table 1: Distribution of the sociodemographic characteristics of participants

Factors	Level	N=20,651	Percent
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			
	Kasem	10,446	50.6
	Nankam	9,292	45
	Buli	372	1.8
	Other	541	2.6
Mother's Age in years			
	≤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
Household socioeconomic status			
	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
Maternal education status			
	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/Elsewhere	6,929	33.5

Under-five mortality rate per 1000 person years of follow-up by background characteristics

A total of 20,651 children followed up for the 7-year period yielded 51,783 person years of observation (PYO). The number of under-five deaths registered during the follow up period was 1056, which is about 4% of the total cohort. Overall, under-five mortality rate was 19.5 per 1000 person years of observation (PYO). Table 2 summarizes the mortality rates by background characteristics.

Table 2: Under-five Mortality rates per 1000 person years of observation by background characteristics in Navrongo, 2007-2012

Factor	Category	deaths	Person years	Mortality rate/1000 pyrs (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)
	Nankam	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)

The results showed that under-five mortality rate per 1000 PYO was higher among males [21.1 (95% CI: 19.4, 22.9) per 1000 PYO] compared to 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 Kasem 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 had the highest under-five mortality rate [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 2). The trend in under-five mortality rates per 1000 live births in the study area from 2007 to 2012 are presented in Supplementary Figure 1.

Causes of under-five deaths

The leading causes of under-five deaths by sex are presented in Table 3. Of the 1,056 under-five deaths from 2007 to 2012, 94% had verbal autopsies done. There was no sex difference in the top causes of U5M in the study area (p=0.191). The top causes of under-five deaths were malaria (19.5%), acute respiratory infections (11.8%), neonatal pneumonia (9.0%), HIV/AIDS (8.9%), birth asphyxia (7.9%) and prematurity (7.6%).

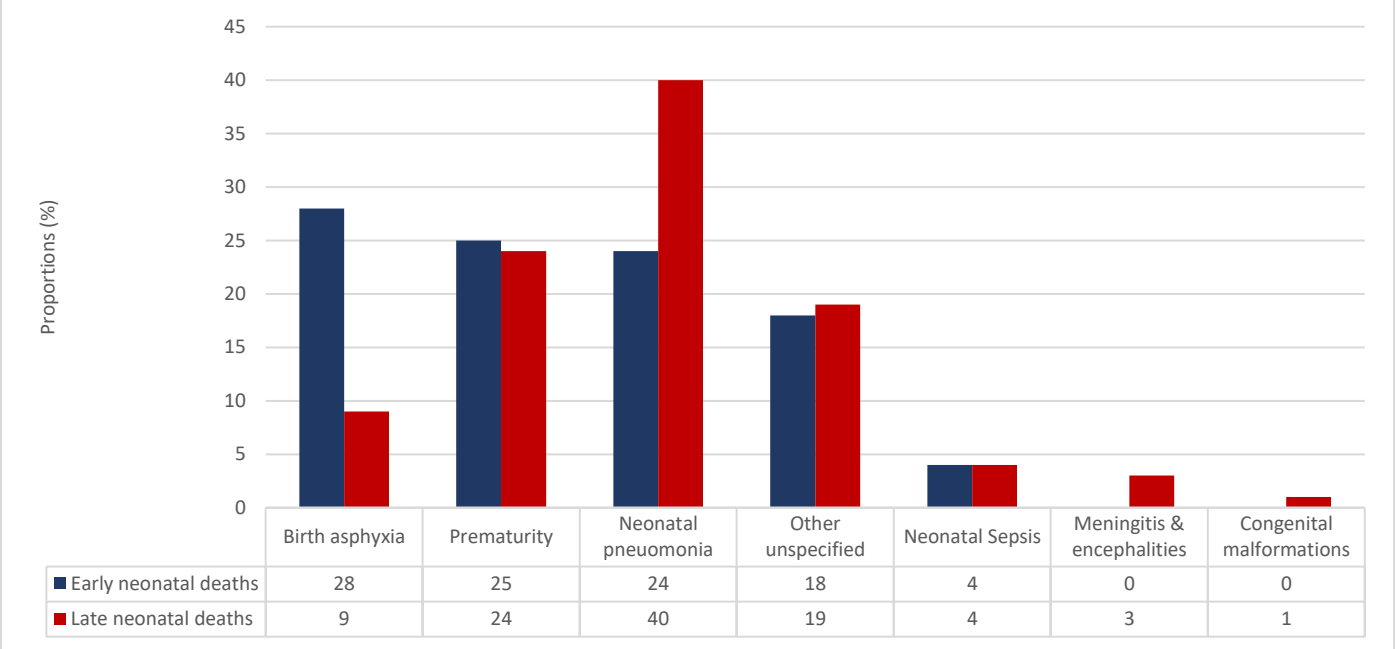
Table 3: Causes of under-five deaths by sex in Navrongo Health and Socio-demographic Surveillance System in Ghana, 2007-2012.

Cause of under-five death	Male	Female	Overall	X^2; p-value
	n (%)	n (%)	N (%)	
Malaria	110 (18.2)	107 (21.1)	217 (19.5)	29.82; 0.191
Acute respiratory tract Infection	68 (11.2)	63 (12.4)	131 (11.8)	
Neonatal pneumonia	51 (8.4)	49 (9.7)	100 (9.0)	
HIV/AIDS	47 (7.8)	52 (10.3)	99 (8.9)	
Birth asphyxia	52 (8.6)	36 (7.1)	88 (7.9)	
Prematurity	51 (8.4)	33 (6.5)	84 (7.6)	
Total	572 (54.2)	484 (45.8)	1056	

We did not find any statistically significant differences in the top cause of under-five deaths by wealth index, maternal education but that of place of residence is statistically significant (p=0.044) (Supplementary Table 1).

Causes of Early and Late Neonatal deaths

Over the analysis period, a total of 309 neonatal deaths were recorded. Most of the neonatal deaths (71%) occurred in the early neonatal period of 0 to 6 days of life. Birth asphyxia (28%), prematurity (25%), neonatal pneumonia (24%) and prematurity (25%) were the major causes of early neonatal deaths. Neonatal pneumonia accounted for 40% of all late neonatal deaths, followed by prematurity (24%) (Figure 1).



	Birth asphyxia	Prematurity	Neonatal pneuomonia	Other unspecified	Neonatal Sepsis	Meningitis & encephalities	Congenital malformations
Early neonatal deaths	28	25	24	18	4	0	0
Late neonatal deaths	9	24	40	19	4	3	1

Figure 1: Causes of early and late neonatal deaths in Navrongo Health and Socio-demographic Surveillance Site in Ghana, 2007-2012

Risk factors associated with under-five mortality

Figure 2 shows the survival probabilities of under-five children in the study area by socio-demographic status. Males had a lower survival rate compared with females (p=0.008). Children born to mothers aged 20 - 30 years had the highest chance of survival as was higher maternal educational level. Single births were less likely to die compared to multiple births. These differences were statistically significant using the log-rank test for equality of survival functions (p<0.001) (Figure 2).

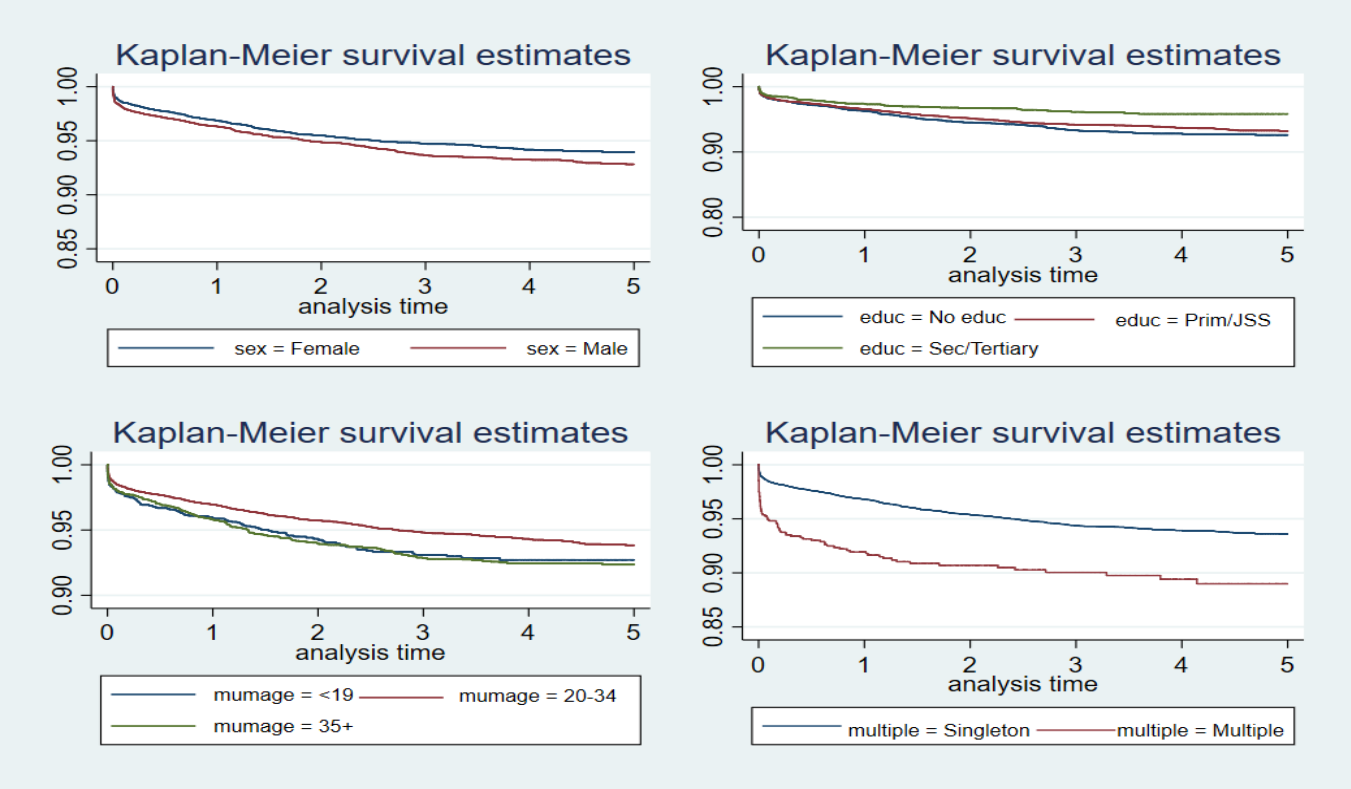


Figure 2: Kaplan Meier Survival estimates curves for under-five mortality by maternal age, education, multiple, and child's sex in the Navrongo Health and Socio-demographic Surveillance System, Ghana, 2007-2012.
Note: mumage - maternal age; edu - maternal educational level; Prim/JSS - Primary/Junior secondary school; sec – secondary

Risk factors associated with under-five mortality by background characteristics

Unadjusted and adjusted hazard ratios showing the risk factors associated with U5M are presented in Table 4. In bivariate analyses, sex, marital status of the mother, maternal age, religion of mother, household socioeconomic status and place of delivery were significantly associated with U5M in the study area. After adjusting for potential confounding variables, being male, children born to unmarried women, maternal age of less than 19 years, children from poor socioeconomic households and home deliveries conferred increased risk of U5M in the study area. Being male was associated with a 20% increased risk of dying compared to being female (Hazard Ratio, HR=1.20, 95% confidence interval (CI) [1.06 - 1.36]; p=0.004). Similarly, children born to single or unmarred women had an increased risk of U5M mothers (HR=1.3, 95% CI [1.18 - 1.59]; p<0.001). Home deliveries, classified as unsupervised deliveries, are associated with a higher risk of U5M compared to health facility deliveries in the study area (HR=1.29, 95% CI [1.12 - 1.48]; p<0.001).

Table 4: Risk factors associated with under-five deaths by background characteristics of children in Navrongo, Ghana, 2007-2012

	Unadjusted HR		Adjusted HR	
Variables	**(95%CI)**	**P-value**	**(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***
Maternal marital status				
Married	1		1	
Not married	1.37 (1.18-1.59)	**<0.001***	1.37 (1.18-1.59)	**<0.001***
Maternal age in years				
≤19	1		1	
20-34	0.77 (0.63-0.93)	**0.007***	0.81 (0.67-0.98)	**0.025***
35+	1.02 (0.83-1.26)		0.98 (0.79-1.22)	
Religion of mother				
Traditional	1		1	
Christianity	0.77 (0.67-0.88)	**< 0.001***	0.87 (0.75-1.00)	**0.008***
Islam	0.97 (0.74-1.27)		1.27 (0.98-1.66)	
Other	0.38 (0.05-2.65)		0.45 (0.06-3.18)	
Wealth quintile				
Poorest	1		1	
Poorer	0.87 (0.73-1.03)	**0.001***	0.87 (0.74-1.03)	0.056
Poor	0.92 (0.77-1.09)		0.93 (0.78-1.11)	
Less poor	0.71 (0.59-0.87)		0.79 (0.65-0.95)	
Least poor	0.59 (0.42-0.83)		0.72 (0.54-0.96)	
Maternal education				
No education	1		1	
Primary/JSS	0.90 (0.78-1.03)	**0.013***	0.98 (0.85-1.13)	0.172
Secondary/tertiary	0.60 (0.47-0.78)		0.79 (0.61-1.03)	
Birth Place				
Health Facility	1		1	

Home/Elsewhere	1.41 (1.23-1.61)	**<0.001***	1.29 (1.12-1.48)	**<0.001***

4. Discussion

This study assessed the causes of under-five deaths and associated risk factors in two districts with a health and demographic surveillance system in Northern Ghana. Majority of under-five deaths were caused by infectious diseases which included malaria, acute respiratory infections, neonatal pneumonia, HIV/AIDS related, birth asphyxia and prematurity. Our findings showed that being a male child, being born to a mother with no formal education, being born to a single or unmarried mother, and being born outside a health facility were associated with increased risk of under-five deaths after controlling for other factors in our adjusted model. Maternal ages of 20-34 years as well as being in a rich household were associated with reduced risk of under-five death.

When we examined the predominant causes of U5M, we identified neonatal pneumonia as the leading cause of death among neonates, followed by prematurity and birth asphyxia. Birth asphyxia was the leading cause of death among early neonates. This observation is consistent with similar findings in Nigeria (19). Birth asphyxia was the topmost cause of early neonatal death in a prospective study involving 4267 children from East, Central and Southern Africa regions (20).

Our finding of pneumonia being the leading cause of neonatal deaths is consistent with an earlier study in the same area from 1998 to 2002 (21). While the dominant causes of neonatal deaths in South Asia are preterm related, the causes of neonatal deaths in Sub-Saharan Africa are dominated by infectious agents especially respiratory diseases such as pneumonia (6).

Our study shows that malaria remains the leading cause of death among children under-five years in the study area with 19.5% of them dying from malaria. This finding is consistent with similar findings from studies in Ghana (12, 21). Other studies in African countries reported up to 17% of under-five deaths attributable to malaria (24). These findings highlight the importance of malaria as the leading cause of under-five deaths in Ghana and Sub-Saharan African.

While malaria deaths are relatively high in children aged 1-4 years, respiratory infections such as pneumonia are high among those below 1 year of age. This may possibly be because the smaller, rapidly developing and or underdeveloped lungs (alveoli and airway dimension) in younger children increase their risk and severity of respiratory infections (25). The high burden and transmission of malaria in the study area may be a major contributor to the high number of malaria deaths. However, the implementation of several interventions such as the introduction of the seasonal chemoprophylaxis (26) and regular use of ITNs may contribute to reducing the burden of malaria deaths in the study area (27). Despite the seasonal variations in malaria occurrence, the increase in vector breeding in the rain season might be contributing to increases in malaria cases and deaths (27). The seasonal harmattan winds might have contributed to the high susceptibility of respiratory illnesses by increasing the reach of infectious agents and the drying of respiratory tract mucosa lining leading to increased penetration of infectious agent (28). These might have contributed to the relatively high deaths from malaria and pneumonia in the study area.

Our study revealed that children born to mothers aged 20-34 years were less likely to die in the first five years of life compared to those born to mothers below 19 years. These findings are consistent with similar studies elsewhere (29–31). The main reason attributed to this observation is that teenage mothers have underdeveloped uterus and hence their children were likely to be premature and suffer adverse uterine conditions before birth (32). A study in northern Ghana showed that children born to women aged 35 years or above were more likely to experience an under-five death compared to women below 20 years of age (33). We did not find any statistically significant difference in the risk of dying between children born to mothers below 19 years and those aged 35 years or older. Studies conducted in new Delhi and northern Ghana did report that children born to women older than 55 years and greater than 35 years respectively had higher risk of U5M (32, 33).

These inconsistent findings call for further studies to elucidate the real mechanism. The findings highlight the possibility of residual confounding in the studies so far and may be an indication that other unmeasured factors may be associated with the risk of mortality other than maternal age.

Our results showed that children in the poorest wealth quintile have higher risks of death compared to those in the higher wealth quintiles. Similar results were observed elsewhere (22). Differences in socioeconomic status have an effect on child survival as evidence suggest that poor families are less likely to have adequate access to healthcare, and are at risk of being infected with pathogens due to inadequate water, sanitation and hygiene facilities (WASH) (34). Other studies suggest that children from poor homes are more likely to die compared to those from rich homes as a result of limited access to life-saving medicines (35). The evidence from these studies adds up to the growing evidence that the poor are at a higher risk of experiencing child mortality (36). Formulation of interventions that aim at economic empowerment of parents, adequate access to healthcare and WASH facilities will help reduce U5M. Universally these social interventions have been identified as key contributors to reducing U5M (37).

Our study observed that children to mothers with higher education levels were less likely to experience U5M compared to those with no formal education. This protective effect of higher education on child mortality is consistent with findings from Zimbabwe (38). A study from Turkey posited that maternal education improves child survival by improving maternal and reproductive lifestyles (38). This observation further offers an avenue to explore short-term maternal educational interventions to complement the long-term plans of improving general education.

We observed that male children were more likely to experience under-five death compared to female children. A United Nations report showed that more countries reported higher mortality rates in males than females. However, a study from China and India observed that female children were more likely to die than male children (39). This finding, however, should be interpreted in the context of widespread sex selection where some families prefer male children to female children.

Children born to unmarried women had increased risk of dying before age 5 compared to children born to married women in our study. This finding is consistent with another study which reported a higher under-five mortality rate among children born to unmarried women in Chad, DR Congo, Mali, Niger and Zimbabwe compared to those born to married women (40). The increased risk is likely due to lack of spousal support to shoulder some of the financial support in health care provision, adequate nutrition, implementation of child survival strategies and the overall health seeking behaviour patterns.

Our study has some limitations we seek to highlight. The distance to the nearest health facility, quality of services rendered and other health system related factors were not measured in this study. These are therefore likely to affect the obtained estimates. We also acknowledge that some other unmeasured factors that can influence mortality may cause residual confounding.

5. Conclusions

Malaria and other infectious diseases are the major causes of under five deaths in the study area. Interventions targeting children with increased risk of dying before age five will greatly minimize these risks and improve overall child survival. Contextual community-based interventions such as improved healthcare utilization and control of infections, especially malaria may improve child survival and contribute to attaining the targets set in the sustainable development goals. Though long-term interventions such as formal education in schools already exist, short term community-based interventions such as health literacy aimed at educating women on child survival techniques would be useful. Economic empowerment such as community gardening and sustainable agriculture to improve infant feeding and healthcare utilization should be considered in intervention formulation.

Author Contributions: SO, TC and PW conceived the study and designed the study methods; SO conducted data extraction, management and analyses; SO wrote the first draft with contributions from EAN and PW; ARO is director of the Navrongo Health Research Center and has oversight for HDSS data; TC and PW supervised the analyses and study; EAN contributed to interpretation of the results and critical review of the manuscript; SO, EAN, TC, PA, ARO and PW reviewed and approved manuscript for submission.

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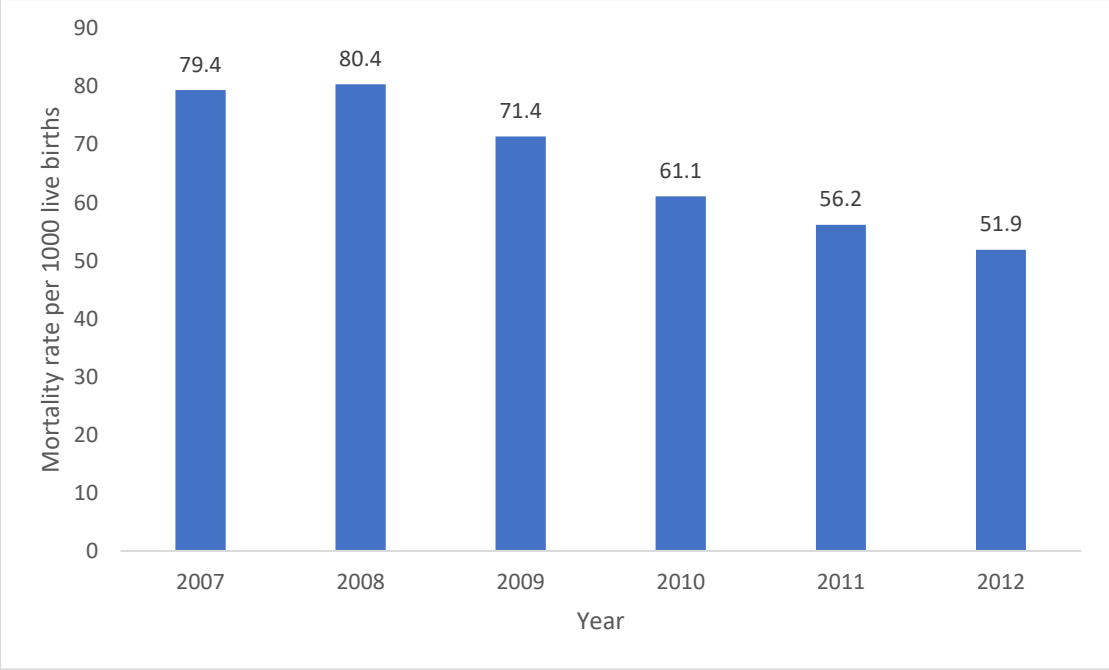
Supplementary Table 1: Causes of under-five deaths by wealth index, maternal education, and place of residence in Navrongo Health and Demographic Surveillance System in Ghana: 2007-2012

Cause of under-five death by Wealth index	Poorest	Poorer	Poor	Less Poor	Least Poor	X2; p-value
	n (%)	n (%)	n (%)	n(%)	n(%)	
Malaria	64(34.2)	52(27.8)	41(21.9)	20(10.7)	10(5.4)	
Acute respiratory tract Infection	34(30.9)	28(25.5)	20(18.1)	17(15.5)	11(10.0)	17.45 0.357
Neonatal pneumonia	36(39.6)	17(18.7)	14(15.4)	13(14.3)	11(12.0)	
HIV/AIDS	29(33.3)	24(27.6)	17(19.5)	12(13.8)	5(5.8)	
Prematurity	24(30.0)	14(17.5)	17(21.2)	18(22.5))	7(8.8)	

Cause of under-five death by maternal education	No education	Prim/JHS	Secondary+	X2; p-value
	n (%)	n (%)	n (%)	
Malaria	70(37.4)	108(57.7)	9(4.8)	12.32 0.138
Acute respiratory tract Infection	34(30.9)	63(57.3)	13(11.8)	
Neonatal pneumonia	32(35.1)	50(55.0)	9(9.9)	
HIV/AIDS	31(35.6)	49(56.3)	7(8.1)	
Prematurity	25(31.3)	41(51.2)	14(17.5)	

Cause of under-five death by place of residence	Urban	Rural	X2; p-value
	n (%)	n (%)	
Malaria	15(8.0)	172(92.0)	9.77
Acute respiratory tract Infection	18(16.4)	92(83.6)	0.044
Neonatal pneumonia	11(12.1)	80(87.9)	
HIV/AIDS	4(4.6)	83(45.4)	
Prematurity	6(7.5)	74(92.5)	



Supplementary Figure 1: Trends in under-five mortality rates per 1000 live births in Kassena Nankana districts (West and East) from 2007-2012