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Survival analysis of factors associated with neonatal mortality in rural areas of Ethiopia: Evidence From the 2019 Ethiopian Mini Demographic and Health Survey.

Msc Thesis

By

Tesfalem Kube

June, 2024

ADDIS ABABA, Ethiopia

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A Thesis submitted to the Center for Population Studies, College of Development Studies, Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science in Population Studies

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This thesis is my original work and has not been presented for a degree of masters in any other University and that all sources and materials used for the Declared by:

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This is to certify that the thesis prepared by Tesfalem Kube entitled: **"Survival analysis of factors associated with neonatal mortality in rural Areas of Ethiopia: Evidence from the 2019 Ethiopian Mini Demographic and Health Survey"** and submitted in fulfillment of the requirement for Degree of Master of Science (in Population studies) complies with the regulations of the University and meets the accepted standards with respect to the originality and quality.

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ACRONYMS AND ABREVIATIONS

AHR	Adjusted Hazard Ratio
ANC	Anti-Natal Care
BIC	Bayesian Information Criterion
CHR	Crude Hazard Ratio
CI	Confidence Interval
CSA	Central Statistics Agency
EA	Enumeration Area
EDHS	Ethiopia Demographic and Health Survey
EMDHS	Ethiopian Mini Demographic and Health Survey
EPHI	Ethiopian Public Health Institute
ESS	Ethiopian Statistical Service
HR	Hazard Ratio
KM	Kaplan-Meier
LR	Likelihood Ratio
MDG	Millennium Development Goal
MOHE	Ministry of Health-Ethioia
NMR	Neonatal Mortality Rate
PH	Proportional Hazards
PNC	Post-Natal-Care
SDG	Sustainable Development Goals
SES	Socio-Economic status
SNNPR	South Nations, Nationalities and Peoples Region
UNICEF	United Nations Children's Fund
UN-IGME	United Nations Inter-agency Group Child Mortality Estimation
WHO	World Health Organization

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ABSTRACT

Background: *Neonatal mortality carries the highest chance of death among all childhood mortality rates. Despite efforts to meet the Sustainable Development Goals, Ethiopia's overall neonatal mortality rate (NMR) was increased from 29 to 33 over the last three decades. This study is aimed to investigate the risk factors affecting neonatal mortality in rural Ethiopia. The study included 4,425 live births from women aged 15-49 in the 5 years prior to the 2019 EMDHS. Multivariate Cox-Proportional hazard modeling and Kaplan-Meier estimates to assess the neonates' survival probability and to analyze the relationship between explanatory variables and neonatal death. The early neonatal mortality rate (ENMR) was 30.96 (95% CI: 26.3, 38) and the NMR was 36.9 (95% CI: 31.7, 42.9) according to the Kaplan-Meier estimations. Several important risk factors were discovered using the Cox-proportional hazard model, including multiple births, advanced maternal age, grand multiparous and multiparous, large household size, immediate breast feeding, and the use of maternal contraceptives have been associated with lower risk of neonatal mortality, whereas male neonates, short birth intervals, and cesarean delivery are linked to higher risk. The highest risk of neonatal death occurred in the first week of life. The main predictors of neonatal death were the sex of the neonate, parity, immediate breastfeeding, multiple birth, maternal contraceptive use, and delivery method. Interventions should focus on improving the accessibility and quality of delivery services, with special attention to multiple births, and promoting antenatal care, family planning, and immediate breastfeeding.*

CHAPTER 1: INTRODUCTION

1.1. Background of the study

The concept of neonatal mortality denotes an infant's death during the first 28 days of life. Sometimes it is called as newborn mortality. Approximately 2.3 million newborn fatalities occurried worldwide, with low- and middle-income nations accounting for the majority of these deaths (WHO, 2022). Furthermore, the first 28 days of a child's life are mostly vulnerable to death with the global average neonatal mortality rate declining from 37 to 18 deaths per 1,000 live births in between the 1990 and 2021 G., representing a 51% reduction in the neonatal mortality rate over that time period (Unicef, 2021).

Neonatal mortality is the focus of Sustainable Development Goal 3.2 of the UN, targeting the minimization of NMR to 12 deaths per 1,000 live births globally by 2030. It may take continuous investment in maternal and newborn health, as well as the application of evidence-based interventions to lower the rates of infant mortality to achieve this aim. There are notable differences in newborn mortality between areas and nations even if the global incidence is dropping. In terms of regional neonatal mortality rates, South Asia and sub-Saharan Africa had the highest rates, with estimates for 2021 of 23 and 27 deaths per 1,000 live births, respectively. In comparison to high income countries in sub-Saharan Africa had ten times neonatal mortality rate, while South Asia had a nine times higher than high income countries. Moreover, the risk of neonatal death is varied amongst countries, with the highest neonatal mortality rate being almost 53 times higher than countries with lowest neonatal countries (UNICEF, 2023).

According to UN-IGME estimations Ethiopia's NMR decreased gradually from about 60 between the time 1990 and 2022 to 27 (UN IGME, 2022). The number of newborn deaths in Ethiopia decreased from over 140,000 in 2000 to fewer than 100,000 in 2019 as a result of the NMR decline, the decline in overall fertility, and the mitigating effect of population growth (EPHI, 2022).

1.2. Statement of the Problem

Almost all neonatal deaths occur in low- and middle-income countries due to limited access to healthcare, nutrition, clean water, and other basic services. Poverty is a key factor driving high infant mortality rates in developing nations. Addressing this critical global health problem requires international attention and intervention, including knowledge-sharing by neonatal nurses to improve maternal-child healthcare worldwide (Ogbolu, 2007).

Reducing under five child mortality is mainly linked to decreasing the neonatal mortality. Hence 47% of the global under five child mortality were occurred on neonates. Globally SDG Target 3.2.2 states is a UN promise made by countries to reduce the neonatal mortality to 12 or fewer (UN IGME, 2022).

In 2023, neonatal mortality accounted for 43% of all infant mortality. If all newborns were able to survive the first week of life, it would result in a one year increase in overall life expectancy (Andersson et al., 2002). Based on current trends, Ethiopia would be predicted to fail achieving the 2030 SDG target of 3.2.2 and hopefully will make it by 2041. Ethiopia's neonatal mortality rate has been trending downward over the previous three decades. However, it surpasses the trend global average rates as well as the combined rates of eastern and southern Africa which had the highest NMR among the other regions of the world (UN IGME, 2022).

According to the 2019 EMDHS, Ethiopia's neonatal mortality rate has slightly increased, despite the country's low decreasing in infant and under-5 mortality rate as compared to the 2016 EDHS, which had infant and under-5 mortality rates of 48 and 67, respectively. Nonetheless, since 2016 to 2019, there has been an increasing in newborn mortality from 29 to 33 NMR (CSA, 2016; Ethiopian Public Health Institute , 2021).

There is still a significant difference between Ethiopia's rural and urban newborn death rates, even if the rural NMR has decreased more swiftly during the last three decades. In rural areas, there are 16 more newborn mortalities per 1000 live births than in urban areas. Ethiopia's rural areas have a neonatal death rate of 37, which is approximately

12% and 36% higher than the national and urban NMR, respectively (Ethiopian Public Health Institute (EPHI) & ICF, 2021). Moreover, in additional research, several studies found that infant mortality risk is higher in rural than in urban areas (Alamirew et al., 2022; Shiferaw et al., 2022; H. Wolde, 2023).

1.3. Objectives of the Study

1.3.1. General objective of the study

The general objective of this study was to examine the factors that determine the time to death or the survival rate of the neonate in rural areas of Ethiopia.

1.3.2. Specific objective of the study

In addition to its broader, general objective, the research also pursued the following specific objectives:

- To identify the risk factors that determine the time to death of neonates;
- To examine the neonate's survival rate over time ; and
- To employ survival analysis techniques to assess the survival status of the neonates and to pinpoint the predictor of time to neonatal death.

1.4. Research Questions

Congruent upon the stated objectives above, the research tried to answer the following research questions.

- ✓ What was the risk factors that determines the time to death of neonates?
- ✓ What does it looks like the survival rates across each week of the follow up time?
- ✓ What is the magnitudes of the risk factor's effect on the neonatal mortality?

1.5. Significance of the study

This research aims to investigate the causes of neonatal mortality issues, especially in Ethiopia's rural areas, across different sub-periods of the neonatal stage. It then suggests interventions that could help reduce neonatal mortality. The study will build on previous research by examining the magnitude of the effect of various factors on neonatal mortality in rural Ethiopia using recent Mini DHS data.

The goal of this study is to identify possible factors that determine the time to death of neonates. This information can then be used to inform policy formulation, guide healthcare providers, and contribute towards achieving the Sustainable Development Goals (SDG-3). The findings can also serve as a reference for future studies in this area.

Given the high neonatal mortality rates in rural Ethiopia and the increase observed in the 2019 EMDHS report nationally and specifically in rural areas (Ethiopian Public Health Institute (EPHI) & ICF, 2021), this study is crucial in identifying the current most influential factors. These insights can then be leveraged to strengthen existing interventions and develop new ones.

1.6. Scope and Limitation of the study

This study focused on exploring the key drivers of neonatal mortality among the rural population of Ethiopia in the five years prior to the 2019 Ethiopia Mini Demographic and Health Survey (2019 EMDHS). The study population was women aged 15-49 years old who had a live birth during this time period.

Since households were the primary sampling units in the survey design, the data was collected by surveying households and interviewing the neonates' mothers directly. So that the information acquired for this study did not include any facility-based data, such as information from health clinics or hospitals.

Additionally, the information related to birth dates was collected by relying on the mothers' recall. This potential recall bias could affect the accuracy of the birth date data, which may in turn impact the results of the study.

CHAPTER 2: LITERATURE REVIEW

2.1. Theoretical literatures on determinants of neonatal mortality

An essay on an analytical framework for the study of the determinants impacting child survival in developing countries is provided by (Mosley & Chen, 2003). They did this by integrating biological and social factors to create a mortality measurement. In medical research, the dependent variable most often measured is morbidity, or the presence of disease in survivors. It is usually calculated as the population's incidence and prevalence of various disease conditions. Socioeconomic aspects are usually ignored or discussed in passing, and the long-term impacts of illness on overall population mortality are routinely dismissed. The development of a proximate determinants approach to the study of child survival is predicated on the following assumptions. Any society's diminished likelihood of surviving is brought about by the combination of biological, environmental, social, and economic factors. Socioeconomic determinants (independent variables) must work through more basic proximal determinants before they can influence process outcomes and illness risk. Certain diseases and nutritional deficiencies observed in a population that persists can be interpreted as biological indicators of the functioning of the proximate determinants. Stunted growth and child death (the dependent variable) result from several disease processes (including their biosocial interconnections). The key to the model is to identify a set of intermediate variables, or proximate determinants, that directly affect the probability of morbidity and death. Any social or economic element that has an impact on child survival must go via these components first. There are five categories in which the proximate determinants fall. The first group consists of maternal variables, which include birth interval, parity, and age. The second category of components consists of environmental pollutants found in food, drink, air, hands, skin, soil, inanimate items, and insect vectors. The third category of factors consists of shortages in calories, protein, and micronutrients (vitamins and minerals). The fourth group of factors is injuries, which can be intentional or unintentional. The last category is personal sickness control, which covers medical attention and preventative measures taken by the individual (Mosley & Chen, 1984).

An author called (Young, 2004) assembled a collection of theoretical models about the factors influencing population health. One of these models is the socioeconomic status (SES), which describes a person's or a household's relative standing in a social hierarchy according to their ability to access and use social and material resources like income and education. Over the course of a person's life, SES can be measured at the individual, household, and community levels. Even though studies frequently only employ one SES indicator, it is possible to examine each SES component separately to ascertain how it affects health outcomes. Education is the most "distal" element influencing work and wealth, which is the most "proximal" factor affecting health. This causal ordering of SES components should also be taken into account. To effectively address the social and economic determinants of health, individual efforts alone are not sufficient. Moreover, a variety of behavioral and environmental factors, including exposure to risks, healthy lifestyles, and the use of preventive health services, might have an impact on health based on socioeconomic status. Stressful life experiences might also affect SES. Psychosocial distress does not directly cause disease; rather, it seems to be a factor in a person's overall susceptibility to illness (Young, 2004). It takes more than individual interventions to effectively address the social and economic determinants of health. SES can also affect health through a range of environmental and behavioral factors, including exposure to risks, healthy lifestyle choices, and use of preventative health services. Stressful situations in life can also affect SES. Rather than acting in a direct, harmful way, psychosocial distress probably adds to a general susceptibility to disease (McIntosh, 1982).

2.2.Empirical Evidence

2.2.1. Global context

The early neonatal phase, the first week of life, has the highest risk of dying within the first 28 days. This risk then declines dramatically in the middle of the second week and remains low during the late neonatal period (Oza et al., 2014). The risk of infant death increased with birth order 2-3 and ≥7 in rural areas, and children born to obese mothers had higher neonatal mortality (Doku, 2022). Newborn mortality was also influenced by socioeconomic status. An Indonesian study found higher mortality risk for mothers with lower education, who did not work outside the home, and who needed to consult others for health decisions (Titaley et al., 2024). neonates, those with delivery complications, cesarean births, and inadequate prenatal care also had higher mortality, especially for male infants (Titaley et al., 2024). Smaller-than-average babies in weight had higher probabilities of dying, especially if their mothers had problems after delivery or underwent a cesarean section, or if they received subpar prenatal care (Akombi et al., 2019; Sougou & Diouf, 2020; zhang et al., 2016). Additionally, the risks were larger for male infants than for female infants (Ezeh et al., 2014; Rumiati & Adisasmita, 2021). Studies in sub-Saharan Africa confirmed a positive correlation between birth frequency and neonatal mortality, but unexpectedly found a negative link between household size and neonatal death. This relationship may be influenced by the age and gender of the household head (Ogallo et al., 2020), which is backed by the findings of (Memon et al., 2023).

2.2.2. Ethiopian context

A study conducted by Yodit (2019) on trends and inequalities of neonatal mortality and its covariates has founded that Neonatal mortality trends have shown a modest fall, which has not been consistent among the chosen equity strata or regions. The annual rate of reduction has also been progressing slowly. Significant disparities are also shown in the estimations of absolute and relative inequality for the various regions. Even though the socioeconomically disadvantaged have a higher death rate than other survey years, income and education-based disparities were only statistically significant in the 2011 survey, which is backed by the study in Brazil (Fonseca et al., 2017). So that the household wealth index is a key factor in neonatal mortality (Asaye et al., 2024; Dessie et al., 2023). And this is agreed by a study conducted in 19 countries by (Islam & Biswas, 2021) showed that mother's and father's educational level and household wealth status minimize the risk of neonatal mortality. Another study by (Shibre et al., 2020) conducted in 2011 EDHS found that inequalities of NMR occurred due to the inequalities of wealth.

A case control study in Ethiopia by Yirgu et al. (2017) found that for every 1000 live births, the newborn death rate was 18.6. The risks of death for neonates born in a household size of more than two were lower than those born in a household size of less than two. Neonatal mortality decreased as family size increased (Deres et al., 2020; Getaneh et al., 2024). Larger mother's parity with the number of 2 - 4 children and 5 and more children have lower risk of losing their neonates (Shiferaw et al., 2022; Yirgu et al., 2017).

Implementing sex-specific public health interventions is necessary to lower newborn mortality in Ethiopia (Garoma et al., 2020). These interventions should primarily target male neonates during pregnancy, childbirth, and the postnatal period (Regesa et al., 2022; H. Wolde, 2023).

Ensuring that all pregnant women are checked for multiple pregnancies and that they receive additional care during pregnancy, childbirth, and the postnatal period is a reasonably simple and inexpensive public health intervention (Garoma et al., 2020). Prematurity, hypoxia, sepsis, and the early age of the newborn period especially in the first 24 hours were the most often found significant drivers of neonatal death in this analysis. Moreover, among the main socioeconomic factors influencing infant mortality were home birth, inadequate prenatal and postnatal care, a delayed start to breastfeeding, and a delay in seeking medical attention (Dessie et al., 2023; Fantahun kibret, 2020).

The place of delivery had a considerable impact on the probability of infant mortality, according to the study of (Mitiku, 2021) findings. As a result, the newborn death rate was lower for babies born in medical facilities than for those born at home. This result is consistent with research done in Ethiopia using DHS data from 2016 and in Afar and Somalia (Regesa et al., 2022), where the authors found that neonates delivered at home had a higher risk of neonatal death than those delivered in medical facilities. This could have happened as a result of inadequate at-home care for mothers and newborns. This finding is alike to a study conducted by (Mitiku, 2021) in 2016 Ethiopian DHS data, and a study conducted in Afar and Somali (Regesa et al., 2022), both authors reported that the risk of neonatal death was less likely for neonates who were delivered in health institutions than delivered at home. This may be occurred due to a lack of adequate maternal and newborn care at home. As a result, the newborn may not receive immediate nutrition during birth, and it may be challenging to address issues as soon as they arise if the mother gives birth at home (Fantahun kibret, 2020).

Less than 18 years age of mothers during delivery had statistically significant correlation with a higher risk of neonatal mortality (Yared et al., 2013). And breastfeeding mothers, and deliveries at medical facilities. Despite the fact that mothers in the 35–49 age range who had multiple births and no ANC visits were statistically linked to a higher risk of infant mortality (Alamirew et al., 2022; Antehunegn & Worku, 2021; Mitiku, 2021; Sahile et al., 2022; H. Wolde, 2023). A panel study in Ethiopia by the rate of neonatal mortality was found to be 26.84 per 1,000 live births (Shiferaw et al., 2022). The risk of neonatal mortality was higher for babies born to mothers who lived in rural areas, mothers who were older, and lower risk neonates born to mothers who were primipara. But, the risk of neonatal mortality was lower for babies born to women who attended technical and vocational level education (Basha et al., 2020; Ewunetu, 2015; Shiferaw et al., 2022; Yirgu et al., 2017).

The risk of neonatal mortality was higher in babies with issues, male babies, babies whose mothers thought they were small, babies who had begun exclusive breast feeding (EBF) after an hour, and women who did not receive postnatal care (Limaso et al., 2020). Neonatal mortality risk factors included the child's sex, wealth index, and place of residence both before and after the birth period (Henok W., 2023). Studies like (Dessie et al., 2023; Gebremichael et al., 2023; Mitiku, 2021) support the findings of a study by (Getaneh et al., 2024) that found a higher risk of baby death during the first 72 hours in cases of repeated births with birth orders six or higher. Conversely, research in Ethiopia found that household size decreased the likelihood of extremely early infant mortality per mother (Deres et al., 2020; Getaneh et al., 2024; Yirgu et al., 2017). The research done in Somalia and Afar by (Regesa et al., 2022) showed evidence that, the mother's educational level, birth type, place of delivery, the child's sex, and the child's size at birth were shown to be statistically significant determinants of neonatal death, which can corroborated findings of the studies of (Asaye et al., 2024; Shibre et al., 2020; Wakgari & Wencheko, 2013; H. Wolde, 2023; H. F. Wolde et al., 2019).

2.3. Conceptual framework of the research

The conceptual framework utilized here is based on one proposed by (Mosley & Chen, 1984) for child health studies. Molly W. and Chen C. provide an analytical framework for studying determinants of child survival in developing countries, integrating biological and social factors to measure mortality, in contrast to medical research that typically focuses on morbidity and ignores long-term socioeconomic impacts. The framework is based on the premise that child survival is influenced by a combination of factors, with socioeconomic determinants working through more proximal factors, and certain persistent diseases and deficiencies serving as biological indicators of these proximate determinants, which fall into five categories. Which are named as maternal factors, environmental exposures, nutritional deficiencies, injuries, and personal sickness and control measures factors (Mosley & Chen, 1984). This study has also reviewed another systematic literature studied by (Hiwot at el., 2022) ; (Asaye et al., 2024; Shibre et al., 2020; Wakgari & Wencheko, 2013; Wolde, 2023; H. F. Wolde et al., 2019) to classify the independent variables into five groups: maternal-related factors, neonate related factors, maternal health-related factors, socio-demographic factors, and environment related factors. Based on the available data in 2019 EMDHS the researcher adapted the (Mosley & Chen, 1984) analytical framework to construct a new conceptual framework as shown in figure 1.

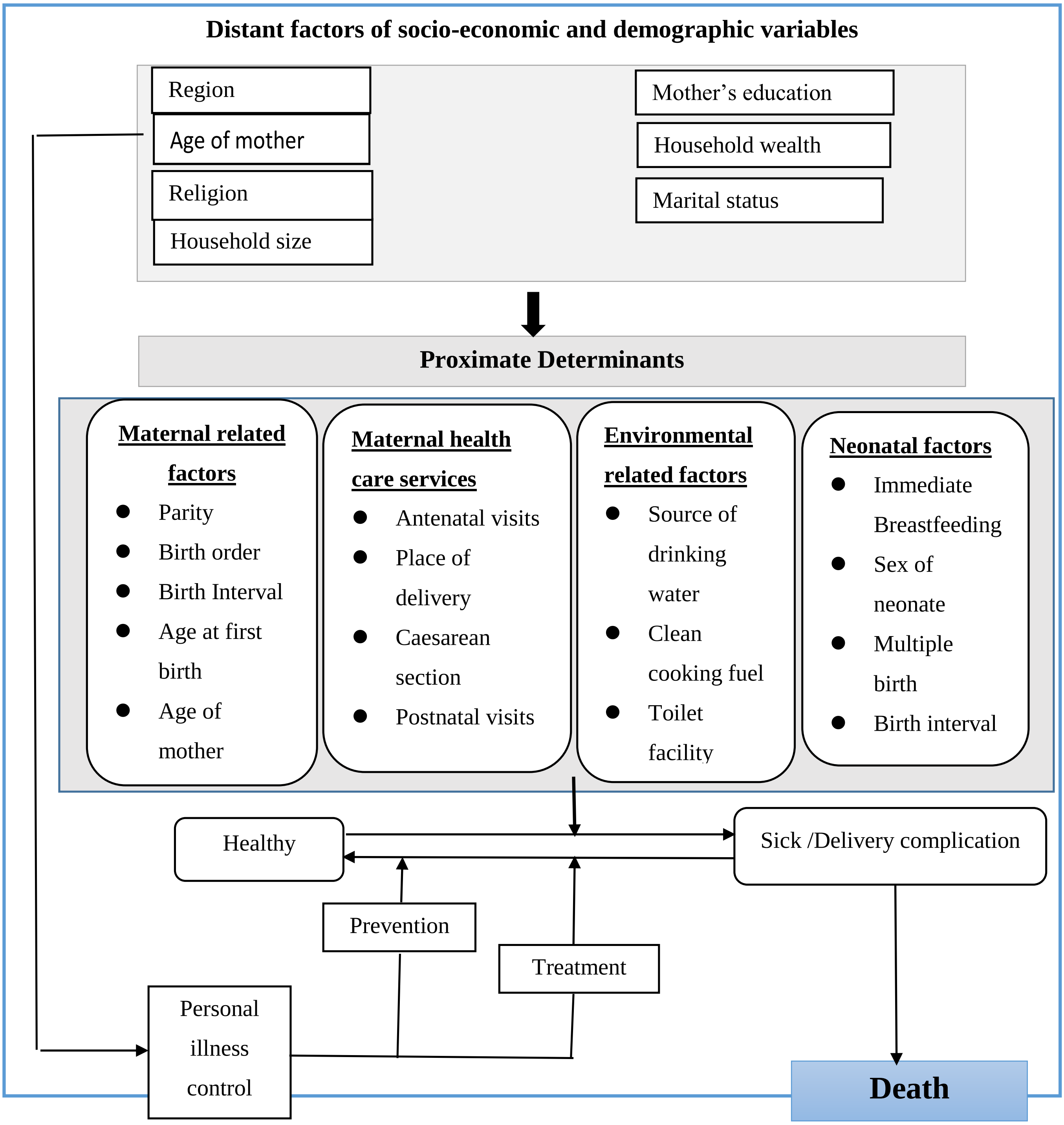

Figure 1.Conceptual framework for the factors influencing neonatal mortality

CHAPTER 3: METHODOLOGY OF THE STUDY

3.1. Data sources

The study aims to identify the factors associated with neonatal mortality of Ethiopian rural areas using data from the 2019 Ethiopian Mini Demographic and Health Survey. A quantitative research approach is appropriate for this study, as quantitative methods focus on quantifying and analyzing variables in order to obtain results. This involves the use and analysis of numerical data using specific statistical techniques to answer questions about who, how much, what, where, when, how many, and how (Apuke, 2017). The 2019 Ethiopian Mini Demographic and Health Survey (2019 EMDHS) was a nationally representative survey conducted by the Ethiopian Public Health Institute (EPHI) with technical support from ICF, which was conducted from June to August 2019. The study described used a retrospective cross-sectional design and drew data from the 2019 EMDHS. The survey is conducted aiming to provide up to date estimates of key demographic and health indicators between 2016 and the next full scale DHS surveys, which have to be conducted every five years. The raw data of this survey freely accessible on the website of DHS program. The data required for this study is retrieved from the 2019 EMDHS data and children dataset.

3.2. Operational Terms

Follow up period: follow up period of the study is 28 days since the birth of the neonate.

Event: The occurrence of death among live births with in the first 28 days of their life (Stewart, 2010).

Censor: Loss to follow up of the neonates before the occurrence of death or alive neonates until the end of the 28 days of follow up times (Stewart, 2010).

Immediate breast feeding: If a child was given a breast feeding within one hour of his birth (World Health Organization, 2023).

Parity: The total number of children ever born to a women (Memon et al., 2023). The categories mothers parity are described in to Primipara, Multipara and Grand multipara(Memon et al., 2023).

3.3. Study Variables

3.3.1. Dependent variable

The response variable of the study is time to neonatal death which is defined as number of days from the time of birth until the end of the follow-up period. This variable is measured as duration for the occurrence of neonatal death or censoring within the first 28 completed days of their life. The neonates are categorized as an event (1 = death) before the end of the follow-up period and those neonates who were still alive but had not reached their 28th day and also neonates lost to follow up were classified as censored (0 = alive).

3.3.2. Independent variables

The independent variables used in the study are listed in table 1 presented below.

Table 1. List of independent variables

S.no	**Type of independent variables**	**Measurement of the variable (Category)**
Demographic and socio-economics variables		
1	Region	1= Tigray 2=Afar 3= Amhara 4= Oromia 5= Somali 6= Benishangul-gumuz 7=SNNPR* 8= Gambela 9= Harari
2	Household size	1= Small (< 4 members) 2= Medium (4 – 6 members) 3= Large (>6 members)
3	Maternal age	1 = (15 - 19) 5 = (35 - 39) 2 = (20 - 24) 6 = (40 -44) 3 = (25 - 29) 7 = (45 - 45) 4 = (30 - 34)
4	Household wealth (in quintile)	1 = lower 2 = Middle 3 = Higher
5	Mothers education	1 = No education 2 = Primary

		3 = Secondary and Higher
6	Religion	1 = Orthodox 2 = Muslim 3 = Protestant 3= Others**
7	Maternal Marital status	1 = Never married/Separated/ Widowed 2 = Married/Living together
8	Sex of births	1 = Male 2 = Female
Maternal and neonatal related variables		
9	Mothers age at first birth	1 = <18 years 2 = >=18 years
10	Contraceptive methods utilization	1=Yes 2=No
11	Parity (Total children ever born)	1= Primi para (1 child) 2= Multipara (2-4 children) 3= Grand Multipara (>4 children)
12	Birth order	The respective order of the neonate (integer)
13	Preceding birth Interval	1= Less than 24 months 2= 24 months and above
14	Multiple birth	1= Single birth 2= Twin
15	Immediate breastfeeding	1=Yes 2=No
16	Season of birth	1=Autumn 2=Winter 3=Spring 4=Summer
Maternal Health Care service utilization related variables		
17	Place of delivery	1= Home 2= Institution
18	Skilled delivery	1=|Yes 2=No
19	Caesarean section	1 = Yes 2 = No
Environment related variables		
20	Source of drinking water	1= protected 2=Unprotected
21	Availability of toilet facility	1=Yes 2=No
22	Utilization of clean cooking fuel	1= Yes 2=No

*SNNPR is the former region of Ethiopia

**Catholic, Traditional and other religion followers

3.4. Inclusion criteria of the study

As per the study's purpose, all live births from women aged 15-49 who were residing in rural areas five years prior to the survey period are included in the study. As shown in figure 2 from the 2019 EMDHS survey 9,150 households (2,790 from urban and 6360 from rural) were selected and 8,663 of them (2,645 from rural and 6,018) were interviewed, yielding a 98.5% response rate. 9,012 (2,999 of them were from urban areas and 6013 from rural ones) eligible women (15-49 years) were found within the selected households for the study. However, 98.6% of the 8,885 women who were interviewed in which 2,951 of whom were from urban areas and 5,934 from rural areas. Finally, out of the 5,934 eligible women, 4425 live births born five years before the survey period were ultimately taken as cases of the study.

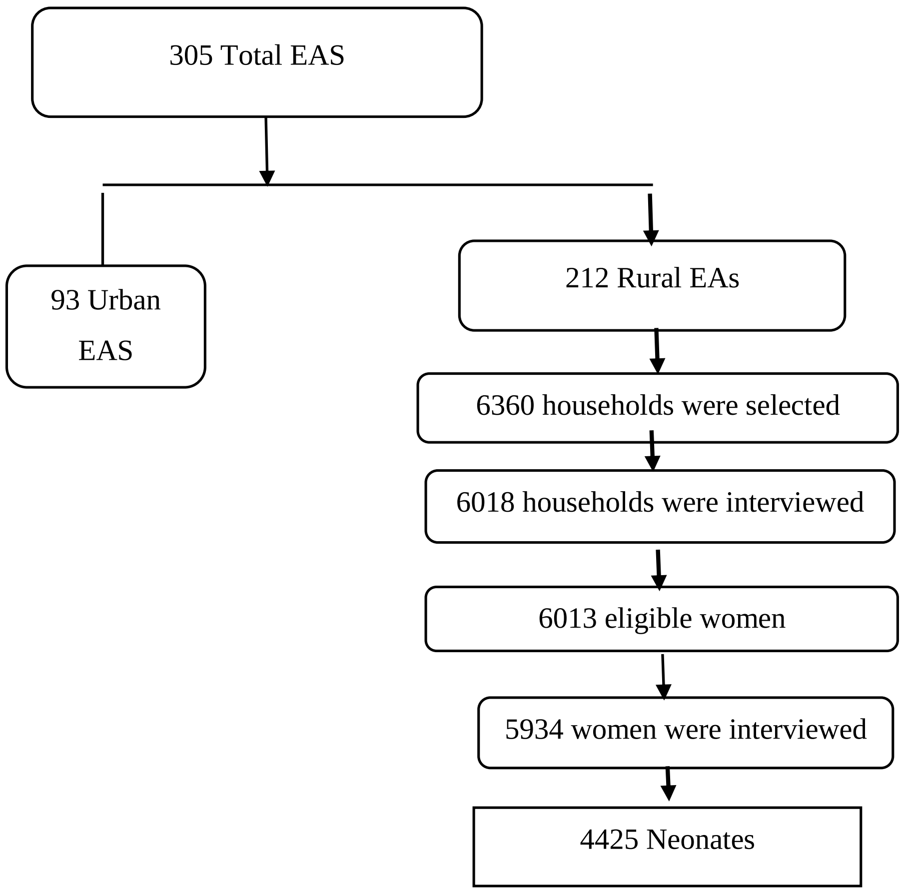

Figure 2.Sampling procedures and selection criteria of the study

3.5. Methods of Data Analysis

STATA version 17 was utilized in this study to perform the intended analysis. Since the dependent variable of the study is time until the event which is the death of neonate occurred the researcher will apply survival data analysis techniques. In this study both types of descriptive and inferential statistics in the process of estimating survival status of the neonates. In predicting the survival status and identifying the factors with significant effect different survival models have been used. Here below some technical terms and function of survival data analysis will be explained.

3.5.1. Survival analysis

this study A set of statistical methods for data analysis known as "survival analysis" involves modeling and analyzing data with a primary termination point; the duration (time-to-event data) of an event prior to its occurrence; the term "time" refers to the time in years, months, weeks, or days between the beginning of an individual's follow-up and the occurrence of an event; the time variable in survival analysis is usually called "survival time" because it indicates the amount of time an individual has "survived" over a specific follow-up period. For this study the time is measured in days. In addition, we use the term "death" to describe the event of interest even when it may actually be a "survive. (Kleinbaum and Klein, 2005).

3.5.1.1. Survival function

Survival is a function that indicates the probability that a neonate will live for longer than 28 days. We must know the lifetime variable's probability density function (PDF), also known as the hazard function, in order to compute the survival function. The lifetime variable's cumulative distribution function (or CDF) is complemented by the survival function.

$$S(t) = P(T > t) = 1 - F(t) = \int_t^{\infty} f(u)du\,,\ t \geq 0 \quad \text{.......................................} \ 1$$

Where $f(t)$ and $F(t)$ are the probability density and the cumulative density functions respectively of a given distribution of the neonates death.

3.5.1.2. The hazard function

The hazard function is the rate of death at time t, given that the neonate has survived until time t. The hazard function is related to the probability density function of the neonate death and the survival function of the neonate by

$\mathrm{h(t)} = \frac{\mathrm{f(t)}}{\mathrm{S(t)}},\ \mathrm{F(t)} = -\frac{\mathrm{d}}{\mathrm{dt}}\ln \mathrm{S(t)}$..2

The cumulative hazard function $H(t)$, is given by

$H(t) = \int_0^t h(u)du = l\,nS(t)$..3

Where $h(t)$, is the hazard function, $f(t)$ is the probability density function (PDF), H(t) is the cumulative hazard function, $F(t)$ is the cumulative of the probability density function and finally, S(t) is survival function at time t.

3.5.1.3. The Kaplan-Meier estimator

The survivor function $S(t)$, which is the likelihood of the neonate surviving past time t or, conversely, the likelihood of failing after t, can be estimated non-parametrically using the Kaplan-Meier estimator. The Kaplan-Meier estimate, sometimes referred to as the product limit estimate of $S(t)$, for a dataset with observed neonate death times, $t1, \dots, tk$, where k is the number of different failure times observed in the data, is given by

$S(t) = \prod_{j|t_j \le t}(\frac{n_j - d_j}{n_j})$……………………………………………………………………..3

If dj is the number of neonate deaths at time tj and nj is the number of neonates at risk at that time. The product is less than or equal to t over all reported failure times (Kaplan & Meier, 1958).

In the context of this study, this formula can be used to estimate the probability of not having neonate death (surviving) at a given time t, where $\widehat{S}(t)$ represents the estimated survival probability at time t, d_j is the number of neonate deaths at time t, and n_j is the number of neonates at risk (who have not had a death or experienced censoring) just before time t.

3.5.1.4. Log rank test

Log-rank test is nonparametric test used to compare the survival functions of two or more groups (Grafféo et al., 2016). In this study, log-rank test is used to compare the neonate's survival distributions between different groups or assess the impact of covariates on survival distribution. The log-rank test determines whether there are significant differences in the survival probabilities (proportions of alive neonates) between the groups over time. The mathematical expression for log-rank test statistic is given by:

$$\chi^2 = \sum \left[\frac{O_1 - E_1}{V_1} + \frac{O_2 - E_2}{V_2} + \cdots + \frac{O_k - E_k}{V_k}\right] \quad \ldots\ldots\ldots 4$$

Within the context of this study, this formula can be used to calculate the log-rank test statistic, where $O1, O2, \ldots, Ok$ represent the observed number of neonates which are dead in each group, $E1, E2, \ldots, EK$ represent the expected number of neonates to be dead, and $V1, V2, \ldots, VK$ are the variances of these expected numbers of death. By conducting the log-rank test, we can assess whether there are significant variations in time to death between different groups and identify factors that may influence the timing and spacing of births.

3.5.1.5. Cox-proportional Hazards Model

The Cox proportional hazards model, also referred to as the Cox regression model, is a statistical technique utilized in survival analysis to examine the relationship between a set of explanatory variables and the time-to-event outcome (D.R. Cox, 1972). In the context of this particular study, the time-to-event outcome being analyzed is the time until the death of a neonate.

Assume that a vector X represents the collection of values for the explanatory variables in the proportional hazards (PH) model. Let the baseline hazard function, which is a function in the reference group of the explanatory variables, be denoted by the function Λ (t). The hazard function for a neonate for whom the values of every explanatory variable that makes up the vector X are zero is represented by λ_0(t). After that, the neonate's hazard function can be expressed as

$$\Lambda(t, X, \beta) = \lambda_0(t) exp(\beta' X) \quad \ldots\ldots\ldots 1$$

Where β is a p x I vector of regression parameters and p covariates (x).

X is a p x I vector of covariate and $\Lambda(t)$ is the baseline hazard function; $\lambda_0(t) > 0$.

The corresponding survival function for Cox-PH model is given by:

$$S(t,x) = [S_0(t)]^{exp \sum_{i=0}^{p} \beta_i X_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

Where, $S_0(t)$ is the baseline survival function?

3.5.1.6. Checking hazard proportionality Assumption

The Cox proportional hazards model assumes proportional hazards, where the hazard ratio remains constant over time. One common method to test this assumption is examining Schoenfeld residuals (Xue et al., 2015). These residuals compare observed and expected covariate values at each event time. Graphical assessments, like Schoenfeld residuals versus time plots, help detect departures from proportional hazards. Additional methods include log-minus-log survival plots (Kuitunen et al., 2023).

3.5.2. Variable selection

Finding a subset of the available inputs that correctly predicts the response variables is done via variable selection. One of the most important steps in the modeling process is choosing appropriate variables to include modeling method. The most common methods of selecting a subset of covariates are purposeful selection, step-wise (forward) selection (Lemeshow & Hosmer, 1999).

3.5.3. Models diagnostics

3.5.3.1. Cox- Snell Residual

The Cox-Snell residuals method is a technique that can be applied to any parametric and semi parametric survival statistical model. The residual plots generated using this method can be used to assess the goodness of fit of the underlying model (Cox & Snell, 1968). The Cox–Snell residual for the i^{th}individual with observed t_i ,r_{ci}, is defined as:

$$r_{ci} = \widehat{H}\left(\frac{t_i}{x_i}\right) = -\log\left[\hat{S}\left(\frac{t_i}{x_i}\right)\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 7$$

Where t_i the observed survival time for individual i, $\widehat{H}(t_i)$ is the cumulative hazard function of the fitted model, x_i is the covariate values for individual i, and $\hat{S}(t_i)$ is the estimated survival function on the fitted model. The corresponding form of residual based particular cox-proportional hazard model can be obtained.

CHAPTER 4: RESULT AND DISCUSSION

4.1. Descriptive statistics

The study included 4,425 infants who were born in the 5 years preceding the 2019 Ethiopian Mini Demographic and Health Survey (EMDHS) and lived in rural areas. Of these rural household infants, 163 had died within the first 28 days of their lives.

The study presented a descriptive analysis of neonatal death and survival status of the neonates across different variables, which are grouped into four categories. The results of descriptive statistics which shows the distribution of neonates with respect the groups, namely socioeconomic/demographic factors, maternal health care services, environmental factors, and maternal/neonatal factors will be presented as follows.

4.1.1. Demographic and socio-economic characteristics

Table 2 shows that, the largest proportion of neonates (14.3%) was from the Oromia region, while the smallest (5%) was from Diredawa city. Tigrai had the lowest neonatal mortality rate (NMR) at 13.1, while Benishangul Gumuz had the highest at 67.1. Most neonates (52.6%) were born to Muslim mothers, who had an NMR of 43, compared to 25.6 for Protestant mothers. The largest age group of mothers was 25-29 (31.9%), while the smallest was 45-49 (2.1%). Most neonates (48.9%) were from households of 4-5 members, but the highest NMR (113.4) was in households with less than 4 members. Nearly 95% of neonates were born to currently married mothers, who had a lower NMR than unmarried mothers. Males accounted for almost 52% of neonates and had a higher NMR than females. Most mothers (60.5%) had no formal education, with a moderate NMR. The majority of neonates (56%) were from low-wealth households, while only 19% were from high-wealth households.

Table 2.Distribution of survival status of neonates across socio-economic and demographic covariates

Covariates	Categories	Total number of births and %	Survival status of the neonate		
			Censored in %	Dead in %	NMR
Region	Tigray	381 (8.6%)	98.7%	1.3%	13.1
	Afar	546 (12.3%)	96.9%	3.1%	31.1
	Amhara	456 (10.3%)	96.1%	3.9%	39.5
	Oromia	632 (14.3%)	95.9%	4.1%	41.1
	Somali	527 (11.9%)	96.2%	3.8%	38
	Benishangul	461 (10.4%)	93.3%	6.7%	67.2
	SNNPR	601 (13.6%)	97.5%	2.5%	25
	Gambela	355 (8%)	96.1%	3.9%	39.4
	Harari	243 (5.5%)	97%	3%	32.9
	dire dawa	223 (5%)	96%	4%	40
Religion of mother	Orthodox	1169 (26.4%)	96.83%	3.17%	31.7
	Muslim	2328 (52.6%)	95.66%	4.34%	43
	Protestant	821 (18.6%)	97.44%	2.56%	25.6
	Others	107 (2.4%)	96.26%	3.7%	37.4
Age of mother	15-19	248 (5.6%)	93.55%	6.45%	64.5
	20-24	861 (19.5%)	95.35%	4.65%	46.5
	25-29	1411 (31.9%)	96.74%	3.26%	32.6
	30-34	935 (21.1%)	97.11%	2.89%	28.9
	35-39	600 (13.6%)	98.00%	2.00%	20.4
	40-44	277 (6.3%)	95.67%	4.33%	43.3
	45-49	93 (2.1%)	89.25%	10.75%	107.5
Household size	1-3 members	432 (9.8)	88.7%	11.3%	113.4
	4-6 members	2164 (48.9%)	96.6%	3.4%	33.7
	more than 6 members	1829 (41.3%)	97.8%	2.2%	22.4

Covariates	Categories	Total number of births and %	Survival status of the neonate		
			Censored in %	Dead in %	NMR
Current marital status of the mother	Currently Unmarried	234 (5.3%)	94.9%	5.1%	51.3
	Currently Married or in union	4191 (94.7%)	96.4%	3.6%	36
Sex of the neonate	Male	2297 (51.9%)	95.9%	4.1%	41.4
	Female	2128 (48.1%)	96.8%	3.2%	32
Education of mother	No education	2752 (62.2%)	96.4%	3.4%	35.2
	Primary	1353 (30.6%)	95.71%	4.3%	42.9
	secondary and higher	320 (7.2%)	97.5%)	2.5%	25
Household wealth status	Low	2812 (63.5%)	96.5%	3.5%	34.5
	Medium	761 (17.2%)	98.5%	4.5%	44.7
	High	852 (19.3)	96.2%	3.8%	37.6

4.1.2. Maternal and Neonatal related covariates

Here is a summary of the key points from the information provided in table 3 45% of neonates were born to multiparous mothers (2-4 live births), while the smallest portion were born to primiparous mothers. Neonates born to primiparous mothers had the highest neonatal mortality rate (NMR) at 44.4. 55% of neonates were born to mothers aged 18 and above, and this group had a higher NMR compared to mothers under 18. Around two-thirds of mothers were not using contraceptive methods, and this group had a higher NMR of 37 compared to those using contraception. 30% of neonates were second or third order births, while first order births were the smallest proportion but had the highest NMR of 54. 3% of neonates were twins, and they had 5 times the NMR of singletons. Neonates with a birth interval of more than 2 years had the lowest NMR of around 24, while shorter intervals and single births had higher NMRs. The highest

NMR of 46 was for neonates born in spring, while the lowest of 25 was for those born in winter.

Table 3. Distribution of neonatal survival status to maternal and neonate related variables

Covariates	Categories	Total births and %	Survival status of the neonate		
			Censored and %	Dead and %	NMR
Total children ever born (Parity)	Primipara (1 live birth)	541 (12.2%)	95.6%	4.4%	44.4
	Multipara (2-4 live births)	2007 (45.4%)	96.4%	3.6%	35.9
	Grand multipara (>4 births)	1877 (42.4%)	96.4%	3.6%	35.7
Contraceptive use	No	3155 (71.3%)	96.1%	3.9%	38.7
	Yes	1270 (28.7%)	96.8%	3.2%	32.3
Birth type	Singleton	4292 (97%)	96.7%	3.3%	32.6
	Twin	133 (3%)	82.7%	17.3%	172.9
Preceding birth interval of the neonate	less than 2 years	890 (20.1%)	94.6%	5.4%	53.9
	More than 2 years	2672 (60.4%)	97.6%	2.4%	23.6
	First birth	863 (19.5%)	94%	6%	60.3
Season of the child birth	Spring	1281 (29%)	95.4%	4.6%	46.1
	Summer	1232 (27.8%)	96.9%	3.1%	30.8
	Autumn	1134 (25.6%)	95.9%	44.1%	40.6
	Winter	778 (17.6%)	97.4%	2.6%	25.7

4.1.3. Maternal Health Care service utilization related covariates

According table 4, around 60% of neonates were born at home, while only 37% of births were assisted by skilled health professionals. There was no observable difference in neonatal mortality rate (NMR) based on whether the birth was assisted by skilled professionals or not.

Giving birth in a health institution did not improve the NMR. Approximately 4% of neonates were born via caesarean section, and their NMR was double the rate of those born vaginally.

In essence, the data indicates that factors besides skilled birth attendance and place of delivery did not significantly impact neonatal mortality rates. However, caesarean births had notably higher neonatal mortality compared to vaginal deliveries.

Table 4. Distribution of neonatal survival status to maternal health care service utilization related variables

Variables	**Categories**	**Total births and %**	**Survival status of the neonate**		
			Censored and %	**Dead and %**	**NMR**
Home delivery	Yes	2725 (61.6%)	96.4%	3.6%	33.4
	No	1700 (38.4%)	96.2%	3.8%	38.1
Skilled Assistance during delivery	No	1793 (63.3%)	96.3%	3.7%	34.6
	Yes	2632 (36.7%)	96.3%	3.7%	35.7
Caesarean section	No	161 (3.6%)	91.9%	8.1%	35.2
	Yes	4264 (96.4%)	96.5%	3.5%	80.7

4.1.4. Environmental related covariates

Despite the potential influence of various environmental factors, the study only included a limited set of variables due to data constraints. These variables were the source of drinking water, availability of toilet facilities, and use of clean cooking fuels. According to the information in Table 5, most of the neonates were born to mothers who used unprotected water sources for drinking. Additionally, half of the neonates' families did not have access to toilet facilities, and nearly all of the neonates' households did not use clean cooking fuels.

Table 5. Distribution of survival status across environmental related factors

Variables	Categories	Total births and %	Survival status of the neonate		
			Censored and %	Dead and %	NMR
Source of drinking water	Protected	1889 (42.7%)	96.7%	3.3%	32.8
	Unprotected	2536 (57.3%)	96.1%	3.9%	39.8
Availability of toilet facility	Yes	2183 (49.3%)	95.5%	4.5%	44.9
	No	2242 (50.7%)	97.1%	2.9%	29
Use of Clean cooking fuel	Yes	34 (0.8%)	94.1%	5.9%	58.8
	No	4391 (99.2%)	96.3%	3.7%	36.7

4.1.5. Descriptive Survival analysis

This study utilized both graphical and tabular methods to present the survival and mortality (failure) rates of the neonates. The specific techniques used includes Kaplan-Meier survival estimate, Nelson-Aalen cumulative hazard estimate, Life table analysis and Log-rank test. These various survival analysis techniques were employed to comprehensively demonstrate the survival and failure (mortality) patterns of the neonates over the 28-day follow-up period.

4.1.5.1. Kaplan – Meier survival and failure estimate results

The study followed approximately 4,425 neonates (newborn infants) for 28 completed days starting from day one after their birth. The minimum follow-up time was 1 day and the maximum was 28 days. In total, there were 123,059 neonate-days of observations or time at risk under observation in the study. Out of the total number of neonates followed, 163 (3.6%) neonates died during the 28-day follow-up period.

In this study, the Kaplan-Meier and Nelson-Aalen estimation techniques were used to understand the survival status of the neonates. Figure 3 presents the Kaplan-Meier survival and failure estimates, which incorporate information from both censored and uncensored observations. The graphs shows that neonate survival decreases rapidly during the first few days after birth, but with a slower slop it continued to decline through the first and second weeks, at the end of the final week it becomes nearly flat which shows very smaller rate of neonatal mortality. Conversely, the graph of also shows the increasing rate of the probability of neonatal deaths was very high during the first couples of days after the delivery of the neonates and become too slow in the third and fourth of the follow up times.

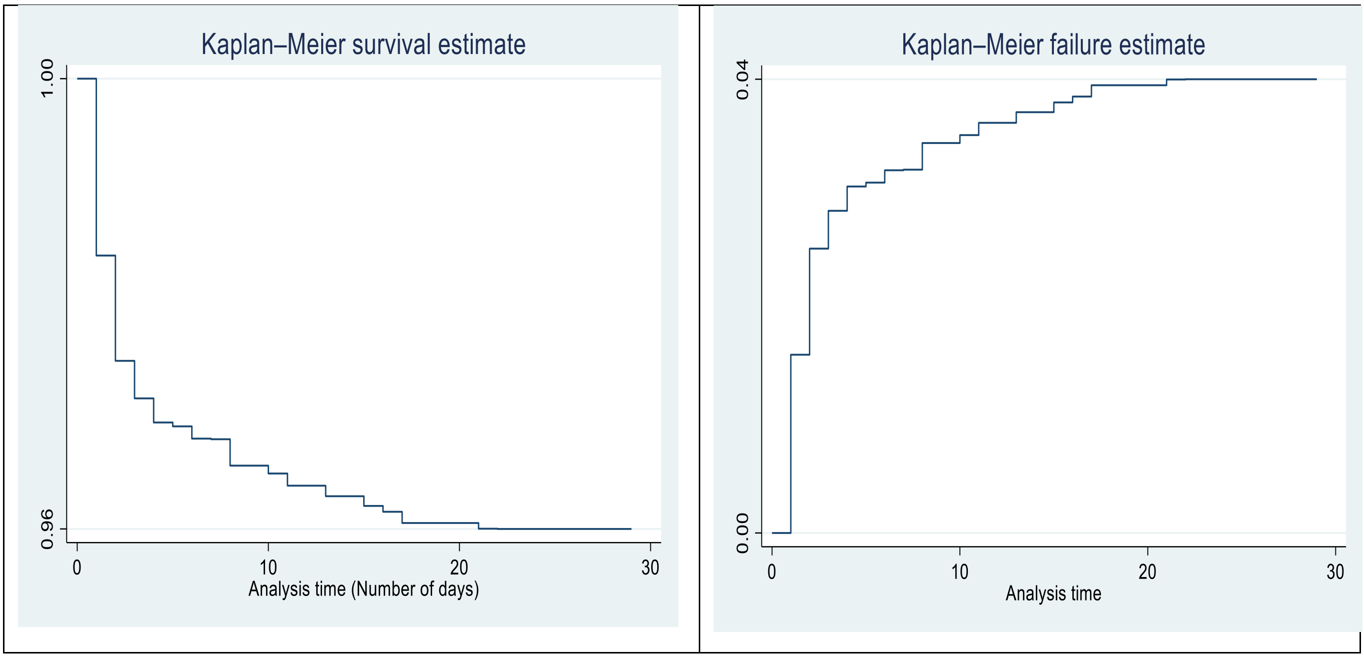

Figure 3. Kaplan-Meier survival estimate of neonates with 95% CI region across the time follow up

Figure 4 presents estimates of the likelihood of neonatal mortality or failure using smoothed hazard estimation and Nelson-Aalen techniques. The graph indicates that the majority of newborn deaths occur in the earlier time periods following birth. Compared to later follow-up periods, the risk of death is highest in the initial days next to their delivery. The risk rate sharply declines in the first 10 days of life. After 10 days, the risk of neonatal mortality becomes more modest. In the final days of the neonate's life, the risk of death is relatively low, with the failure function's slope being nearly flat. In general, most neonatal deaths take place within the first week of life.

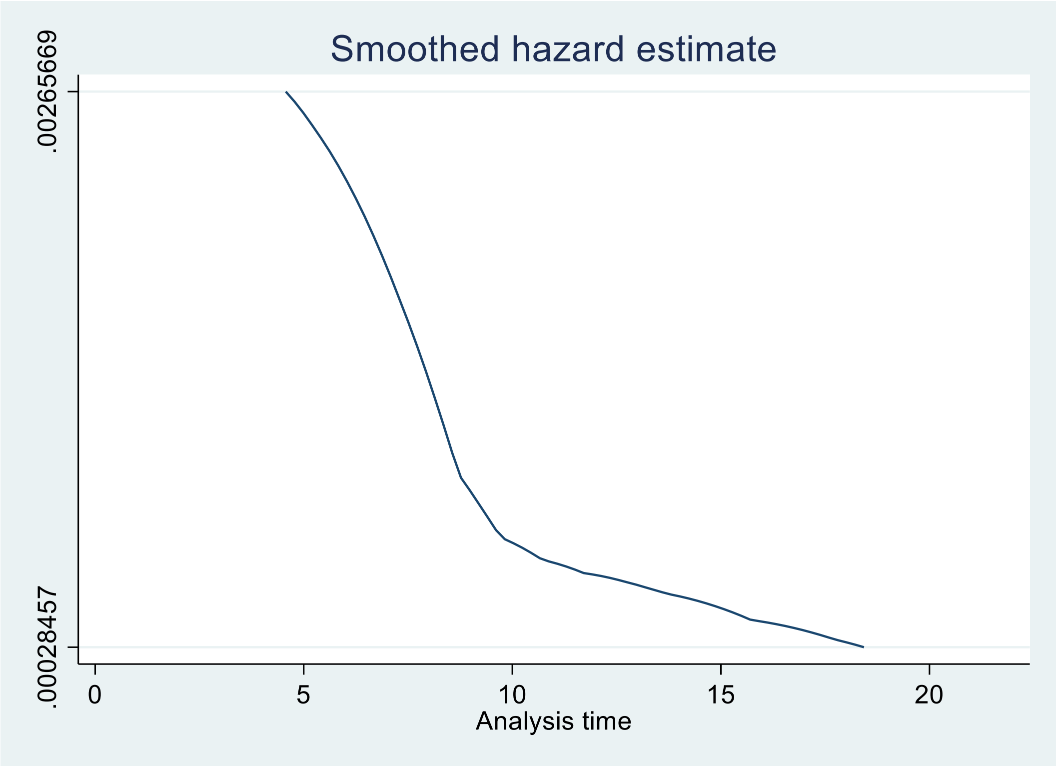

Figure 4. Nelson-Aalen Cumulative Hazard estimate and Smoothed hazard estimate of neonates across follow up times

4.1.5.2. Survival life table

The data presented in Table 6 indicates that the vast majority of neonatal deaths occurred very early in lifetime. Specifically, 84% of neonatal deaths happened within the first week after birth, and around 94% occurred within the first two weeks. In contrast, only 6% of neonatal deaths took place after the initial two weeks following delivery. During the first week of life, the neonatal mortality rate (NMR) was 36.9 per 1,000 live births (95% CI: 31.7, 42.9), while the early neonatal mortality rate (ENMR) was 31 per 1,000 live births (95% CI: 26.3, 38.0).

Table 6. Survival life table of neonates with respect the follow up times

Time interval		Number of entries at the beginning	Number of Deaths	Number of withdrawals	Cumulative probability of Survival	Std. error	[95% conf. int.]	
0	1	4425	74	0	0.9833	0.0019	0.979	0.9867
1	2	4351	31	3	0.9763	0.0023	0.971	0.9804
2	3	4317	11	4	0.9738	0.0024	0.968	0.9781
3	4	4302	12	6	0.9711	0.0025	0.965	0.9756
4	5	4284	3	3	0.9704	0.0025	0.964	0.9750
5	6	4278	4	3	0.9695	0.0026	0.964	0.9742
6	7	4271	2	2	0.9690	0.0026	0.963	0.9737
7	8	4267	6	5	0.9677	0.0027	0.962	0.9725
8	9	4256	0	3	0.9677	0.0027	0.962	0.9725
9	10	4253	1	4	0.9674	0.0027	0.961	0.9723
10	11	4248	7	2	0.9658	0.0027	0.960	0.9708
11	12	4239	0	2	0.9658	0.0027	0.960	0.9708
12	13	4237	2	5	0.9654	0.0028	0.959	0.9704
13	14	4230	0	2	0.9654	0.0028	0.959	0.9704
14	15	4228	1	1	0.9651	0.0028	0.959	0.9702
15	16	4226	5	4	0.9640	0.0028	0.958	0.9691
16	17	4217	2	1	0.9636	0.0028	0.957	0.9687
17	18	4214	0	2	0.9636	0.0028	0.957	0.9687
18	19	4212	0	1	0.9636	0.0028	0.957	0.9687
19	20	4211	0	1	0.9636	0.0028	0.957	0.9687
20	21	4210	1	2	0.9633	0.0028	0.957	0.9685
21	22	4207	1	1	0.9631	0.0028	0.957	0.9683

22	23	4205	0	2	0.9631	0.0028	0.957	0.9683
23	24	4203	0	2	0.9631	0.0028	0.957	0.9683
24	25	4201	0	6	0.9631	0.0028	0.957	0.9683
25	26	4195	0	1	0.9631	0.0028	0.957	0.9683
26	27	4194	0	4	0.9631	0.0028	0.957	0.9683
27	28	4190	0	2	0.9631	0.0028	0.957	0.9683
28	29	4188	0	4188	0.9631	0.0028	0.957	0.9683

4.1.6. Results of log-rank test of covariates

Table 7 shows the bivariate relationship between various potential factors and neonatal survival. In the table factors with light black color are not significantly associated with survival function of the neonates. The results indicate that only 11 variables have a statistically significant association with a p-value less than 0.05. The most strongly correlated demographic and socioeconomic factors with neonatal mortality are the mother's age, marital status, household size, and the newborn's sex. These factors appeared to impact the neonate’s chances of survival. Additionally, maternal factors like contraceptive use, immediate breastfeeding practice, and birth type, as well as neonatal related factors such as season of birth and preceding birth interval, are also linked to the risk of neonatal death.

Table 7. Results of log rank test of covariates that shows the association of covariates with survival function.

S.no	Covariate	DF	Chi-	P-value
Demographic and socio-economic covariates				
1	Region	10	8.05	0.5291
2	Religion	3	8.06	0.0447
3	Mother's age	2	37.58	0.0000
4	Mother's current marital status	1	5.22	0.0223
5	Sex of neonates	1	10.66	0.0011
6	Household size	2	131.46	0.0000
7	Mother's education	2	2.22	0.2552
8	Household's wealth status	2	0.55	0.7605
Maternal and neonate related covariates				
9	Mother's live births during lifetime (parity)	2	3.36	0.1866
10	Age at first birth	2	0.43	0.8073
11	Contraceptive use of mother	1	4.87	0.0273
12	Multiple birth	1	22.50	0.0000
13	Preceding birth interval	2	33.69	0.0000
14	Immediate breastfeeding	1	45.59	0.0000
15	Birth order	14	37.73	0.0003
16	Season of birth	3	8.92	0.0303
Health facility utilization related covariates				
17	Home delivery	1	1.51	0.2192
18	Skilled assistance during delivery	1	0.82	0.3657
Sanitary related covariates				
19	Source of drinking water	1	1.77	0.1833
20	Use toilet facility	1	0.00	0.9655
21	Use of clean cooking fuel	1	0.99	0.3851

4.2. Model checking and diagnosis

In this study, the researchers performed tests to check the underlying assumption of proportional hazards, which is a key requirement for this type of survival analysis. Additionally, we assessed the overall goodness-of-fit of the model to ensure that it adequately captured the patterns and relationships within the data.

4.2.1. Test proportional hazard assumption

The fitted cox-proportional hazard model must be diagnosed in order to apply and understand the test proportional hazard assumption. The fundamental premise of the proportional hazard model is that the hazard ratio remains constant across time. In other words, regardless of the time of the subjects are followed, the chance dying remains constant. With a p-value of 0.251, the overall hazard model provides sufficient evidence of proportionality. According table 8 there is sufficient evidence to conclude that the hazard model is proportionate to all other factors. The covariates with the strongest evidence include the sex of neonates, birth order, children ever born, and source of drinking water.

Table 8. Results of Schoenfeld residuals test for the assumption of proportional hazard

Covariates	Time function: Analysis time	chi2	Degree of	Prob>chi2
Age of mother	0.101	2.120	1	0.146
Household size	-0.092	2.450	1	0.117
Marital status of mother	0.040	0.280	1	0.596
Sex of the neonate	0.021	0.080	1	0.777
(parity)	0.015	0.050	1	0.822
Immediate breast feeding	-0.124	2.730	1	0.099
Use of contraceptive	0.156	4.160	1	0.041
Multiple birth	0.077	1.700	1	0.192
Birth order	-0.013	0.040	1	0.839
Preceding birth interval	0.092	1.810	1	0.179
Birth season	0.086	1.220	1	0.269
Delivery by caesarean	-0.048	0.380	1	0.537

Source of drinking water	0.000	0.000	1	0.999
Global test		**15.960**	**13**	**0.251**

4.2.2. Assessment of overall goodness of fit of the model

The Cox-Snell residual test is a method used to assess the goodness of fit of a model. In this investigation, the researchers utilized this approach. As illustrated in Figure 5, the cumulative hazard function estimates are plotted against the Cox-Snell residuals, which were predicted by the stepwise multivariate Cox proportional regression analysis. The Cox-Snell residuals are approximately represented by the 45-degree straight line in this plot. The fact that the cumulative hazard estimates follow this 45-degree line of Cox-Snell residuals suggests that the stepwise multivariate Cox proportional regression model adequately represents the data. Since the model assumptions are met, the researcher can now proceed to interpret the results of the Cox proportional hazards model, such as the hazard ratios and their statistical significance, with confidence.

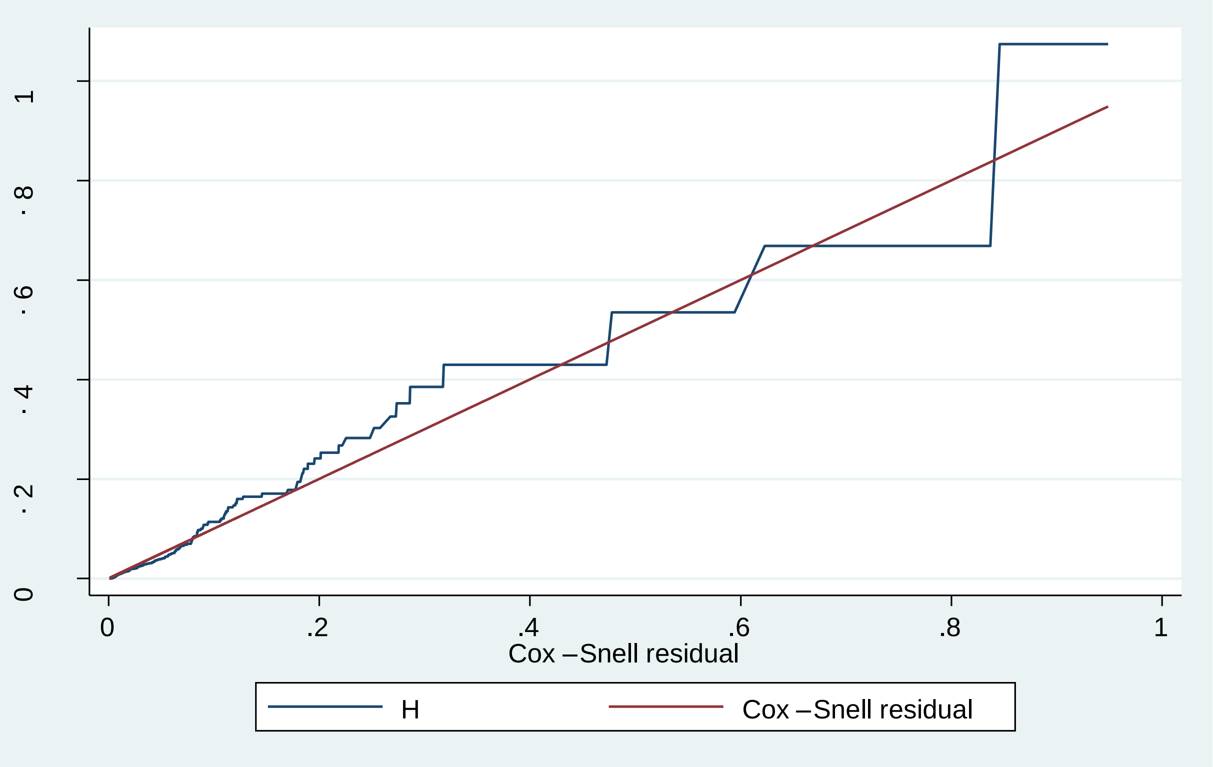

Figure 5. Plot of Cox-Snell residuals against cumulative hazard function estimates

4.3. Cox-proportional hazard Analysis

This section describes the development of a Cox proportional hazards regression model to examine the impact of various covariates on the survival status of neonates throughout the follow-up period. The model involves regressing the covariates against the neonates' hazard rate. Before finalizing the regression model, the researchers had had to go through several model selection procedures and model diagnostic procedures including fitting bivariate and multivariate Cox proportional hazards models, and evaluate the impact of each candidate covariate before selecting the final variables for the multivariate model.

4.3.1. Result of Bivariate Cox proportional hazard

Table 10A which is in appendix presents the results of a bivariate Cox-proportional hazard analysis examining the impact of 21 potential covariates on the risk of neonate dying. The analysis found that factors such as the mother's age at first birth, region, education, household wealth, parity, use of health facilities during delivery, and sanitation-related variables were not significantly associated with the hazard function or risk of dying of neonates. Similarly, the mother's age, religion, household size, marital status, the neonate's sex, immediate breastfeeding, multiple births, preceding birth interval, and delivery by Caesarean section have statistically significant association with the outcome. As we can observe the effect of variables on the model that the household size and immediate breastfeeding have largest effect by increasing the log likelihood by 41 and 21 respectively, from the empty model to the full model. In contrast, the factors with the lowest influence were the mother's age at first birth and the presence of a toilet facility, with increases of 0 and 0.01 in the log likelihood, respectively.

4.3.2. Results of Multivariate cox-proportional hazard model

The forward stepwise estimation (D. Hosmer, 1999) was using to construct the multivariate Cox proportional hazard model, using all candidate variables, identified several significant predictors of neonatal mortality with p-values less than 0.25. Covariates such as region, mother's religion, household wealth status, mother's educational level, age at first birth, delivery place, and skilled assistance of delivery, source of drinking water, toilet facility and use of clean cooking fuel was excluded from the model. These included maternal factors such as marital status, household size, parity, contraceptive use, and delivery method, as well as infant factors like sex, breastfeeding, and birth season. Finally, we have developed the final multivariate cox-proportional model after adhering to all of these model development procedures and by following all necessary model diagnostic procedures that satisfies minimum criteria. Therefore, after the researcher completes the model diagnostics and checking processes, they are permitted to interpret the results of the final model.

According to the model shown in Table 9, neonates born to mothers in the 35–39 age range had a 51% lower mortality risk than those born to mothers in the 25–29 age range, while newborns born to mothers in the 40–44 age range had a 2.21 times greater risk. Household size was also important, with medium (4-6 members) and large (>6 members) households having 86% and 91% lower risks, respectively, compared to small (<4 members) households to the neonate death in the household. Female neonates had a 36% lower mortality risk than males. Mothers with 2- 4 children ever born and mothers with five and more children ever born increased the risk by 3.59 and 5.75 times, respectively, compared to primi parous mothers (mothers which have only one child ever born). Delayed breastfeeding practice and lack of maternal contraceptive use were also significant risk factors, increasing mortality by 2.29 and 1.77 times, respectively.

Additionally, twin births, short birth intervals (<2 years), season of birth and cesarean section were associated with higher neonatal mortality. Neonates with a birth spacing of two years or more had a 48% lower risk of death than those with a birth interval of less than two years, and those born in the summer had a 41% lower risk of dying compared to spring births.

Table 9.Results of stepwise multiple Cox- Proportional hazard model

Covariates	AHR	SE	Wald (χ^2)	p-value	AHR [95% Conf. Interval]	
Age of mother						
25 – 29 (Reference)	1					
15 - 19	1.442	0.468	1.13	0.259	0.763	2.725
20 - 24	1.222	0.31	0.79	0.431	0.743	2.009
30 - 34	0.809	0.236	-0.73	0.468	0.456	1.434
35 - 39	0.409	0.158	-2.31	0.021*	0.191	0.874
40 - 44	2.21	0.797	2.20	0.028*	1.090	4.479
45 – 49	1.548	0.929	0.73	0.467	0.478	5.017
Marital status of the mother						
Unmarried (Reference)	1					
Married	0.719	0.22	-1.08	0.281	0.395	1.31
Household size						
< 4 (Reference)	1					
4 – 6 members	0.137	0.034	-8.10	0.000***	0.085	0.222
>=7 members	0.086	0.029	-7.24	0.000***	0.044	0.167
Sex of the neonate						
Male (Reference)	1					
Female	0.641	0.111	-2.56	0.011*	0.456	0.901
Number of live births ever born (Parity)						
Primi-para (Reference)	1					
Multiparous (2 – 4 live births)	3.59	1.156	3.97	0.000***	1.910	6.747
Grand Multiparous (>4 live births)	5.748	2.729	3.68	0.000***	2.267	14.574
Immediate breast feeding						
Yes (Reference)	1					
No	2.286	0.444	4.26	0.000***	1.563	3.345

Covariates	AHR	SE	Wald (χ^2)	p-value	AHR [95% Conf. Interval]	
Contraceptive use of the mother						
Yes (Reference)						
No	1					
	1.771	0.34	2.98	0.003**	1.216	2.579
Type of birth						
Single (Reference)	1					
Twin	2.935	0.995	3.18	0.001**	1.511	5.702
Birth order	1.036	0.08	0.46	0.648	0.89	1.205
Preceding birth interval						
Less than two years (Reference)	1					
Two and above years	0.515	0.107	-3.20	0.001**	0.343	.773
First birth	0.981	0.33	-0.06	0.954	0.508	1.895
Season of birth						
Spring (Reference)	1					
Winter	0.749	0.167	-1.30	0.195	0.484	1.159
Autumn	0.804	0.172	-1.02	0.31	0.528	1.224
Summer	0.593	0.154	-2.01	0.044*	0.357	0.986
Birth by Caesarean section						
Yes (Reference)						
No	1					
	0.479	0.141	-2.50	0.012*	0.269	0.853
Source of drinking water						
Unimproved (ref.)	1					
Improved	1.283	0.227	1.41	0.158	.908	1.814

The log-likelihood of the final model is -1135.81, Statistical significance level is denoted by * for p-value<0.05, ** for p-value<0.01, *** for p-value<0.001

4.4. Discussion

The purpose of this research is to estimate the effect of covariates on neonatal mortality in Ethiopia's rural areas through using data obtained from the 2019 Ethiopian Mini-DHS. In order to accomplish the goal, the Cox-proportional hazard model was applied to study the numerous associated risk factors that are present in the Mini-DHS data with neonatal mortality. From the result of the model mother's age with age group of 35-39 and 40-44, household size, sex of neonates, parity of the mother, immediate breastfeeding, contraceptive methods utilization of mothers, multiple birth, preceding birth interval, season of birth and delivery by caesarean section are statistically significant to predict the neonatal mortality which are variable demographic, maternal and neonatal related variables supported by the conceptual framework.

According to the surviving life table, the first week accounts for 84% of neonatal deaths, with an early neonatal mortality rate of 30.96 in Ethiopia's rural districts. This is much higher than the global level proportion of the death early neonates which is 75% (World Health Organization, 2024). In contrast to the first week, the mortality rate dawn falling in the subsequent weeks as the follow-up period extends to the fourth week. The findings of (Fantahun kibret, 2020), a different study that examined newborn mortality across Ethiopia, suggest that premature birth and the early stages of the neonatal period may be important proximal factors in determining neonatal death. It also agreed with findings from other studies, including those conducted in Ethiopia by (Dessie et al., 2023; Gebremichael et al., 2023) and in 186 countries by (Oza et al., 2014), which discovered that the majority of newborns die in the first week of life.

Maternal age has been found as one of the risk factors of the neonatal mortality, especially in the age group of 40 – 44 the risk of death is 2.21 times higher than age group of 25 – 29. This is consistent with recent research that indicates older women are more likely to experience newborn death (Ewunetu, 2015; Grady et al., 2017; Kim et al., 2021; Shiferaw et al., 2022; Yirgu et al., 2017). This study observed that the neonates whose mothers are between the ages of 35 and 39 have the risk death 59% lower than the age group of 25 -29. However, this result is different as compared to other researches which consider this age group as older mothers and claim that this group has a similar risk of mortality to those older mothers (Ewunetu, 2015; Grady et al., 2017; Shiferaw et al., 2022). This decrement of the mortality could come due to the better experience of mothers to take care of their child, large household size could help the mothers in handling the child and increasing economic sources of the family. Recent nationwide data indicates that the age-related risk of early neonatal mortality becomes significant exclusively for mothers aged 40 years and older. Conversely, mothers between the ages of 35 and 39 do not exhibit an increased risk for early neonatal mortality (Tamir et al., 2023).

Household size is another risk factor that has been proven to be strongly associated with the probability of neonatal mortality. Compared to small households (less than four members), neonates born into households with four to six members had an 86% lower chance of dying, while large households (more than seven members) have a 91% lower risk of dying. This finding verified the previous studies such as (Deres et al., 2020; Getaneh et al., 2024; Yirgu et al., 2017) and (Memon et al., 2023; Ogallo et al., 2020; Takramah & Aheto, 2023), which are conducted in Ethiopia and abroad respectively. Each of these studies discovered an inverse relationship between the size of the neonate's household and neonatal mortality. The neonatal mortality in large household size increased due having additional economic source which is generated by other members of the household which is more likely to happen in such households. Additionally, the study discovered that the risk of death is 36% lower in female neonates. This has been supported by numerous studies, like (Ezeh, 2017; Regesa et al., 2022; Rumiati & Adisasmita, 2021; H. Wolde, 2023) which are from internal and external of the country.

Among the possible candidates of risk factor in which their data is available in the EMDHS, only parity, the mother's use of contraception, multiple births, preceding birth interval, immediate breastfeeding, the season of birth, and cesarean delivery have been attributed to an increased risk of newborn death among the various maternal and neonatal related risk factors. The risk of neonate death for multipara mothers (mothers with two to four children) is 3.59 times higher than that of primi-para mothers (mothers with one live birth). Parity, or the total number of children ever born, is the risk factor that has been linked to newborn mortality the most frequently. Neonates born to grand multipara mothers (mothers with more than four live births) are at 5.75 times higher risk of dying than neonates born to primi-para mothers. This discovery could be substantiated by (Kananura et al., 2016; Martinelli et al., 2019; Rumiati & Adisasmita, 2021; Shibre et al., 2020; Titaley et al., 2024; Wakgari & Wencheko, 2013) which generally all comes to the conclusion that the chance of newborn death rises with the mother's parity. The findings showed that neonates with two years or more of preceding birth interval had a 48% higher chance of dying than those with less than two years of preceding birth interval. This result was supported by earlier studies by (Antehunegn & Worku, 2021; Girma et al., 2022), which found that neonates with fewer than two preceding birth interval were more likely to die than those with two or more preceding birth intervals. This study also confirmed that multiple births is a neonatal-related covariate that is associated with neonatal death. Neonates who were born twins (two or more) had a 2.94 fold increased risk of dying compared to single births, as indicated by the studies of (Asaye et al., 2024; Basha et al., 2020; Islam & Biswas, 2021; Sahile et al., 2022; H. F. Wolde et al., 2019). The immediate breastfeeding or having breastfeeding within one hour after delivery of the neonates reduces the risk of dying by 2.3 times. The result of (Alamirew et al., 2022; Asiimwe et al., 2019; Mitiku, 2021) are consistent with this finding. Compared to neonates born in the spring (September to November), those born in the summer (the rainy season) had a 41% decreased chance of dying. Unlikely the study by (Yared et al., 2013) had the opposite finding. One of the covariates that has a statistically significant impact on the neonatal death is the mother's usage of contraception. According to the study, neonates born to moms who did not use contraceptive methods had a 1.77 times higher chance of dying than their counterparts that was very close with finding by (Akombi et al., 2019) conducted in Democratic republic of Congo. Lastly, this study found that the covariate of neonates delivered via caesarean section increases their risk of dying by 52%. This finding is consistent with reviews of other earlier studies that have been conducted (Akombi et al., 2019; Sougou & Diouf, 2020; Woday Tadesse et al., 2021; Ye et al., 2016).

Even if, identifying the effect the socio-economic (educational level and household wealth), maternal health care service (antenatal , deliver and postnatal health care) and environmental related (source of drinking water, toilet facility and clean cooking fuel) related variables was among the specific objectives, the studies found out that these variables have not significant effect on neonatal mortality. However in most studies socio-economic variables significantly determined the neonatal mortality (Asaye et al.,

2024) and (Fonseca et al., 2017; Grady et al., 2017; Islam & Biswas, 2021; Shiferaw et al., 2022). Delivery related variables also are not significance unlike the studies of (Sahile et al., 2022; Takramah & Aheto, 2023). Toilet facility is significant predictor of neonatal mortality in the study by (Sahile et al., 2022).

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This comprehensive study was meticulously conducted utilizing data from the 2019 Ethiopian Mini-DHS focusing on a sample of 4425 neonates who were born within the five years leading up to the survey. The primary objective of this research was to identify the key risk factors associated with neonatal mortality. To analyze the gathered data effectively the study employed the Kaplan-Meier survival estimation technique alongside the Cox-proportional hazard model which are both established methodologies in survival analysis.

The findings of this study revealed that a substantial proportion of neonatal deaths amounting to 84% occurred during the critical first week of life. This is much higher than the global level proportion of the death early neonates which is 75% (World Health Organization, 2024). Alarmingly more than half of these fatalities transpired on the day of delivery underscoring the vulnerability of neonates in their initial hours. The analysis also highlighted some demographic variables that significantly influenced neonatal mortality rates. Specifically the age of the mothers particularly those in the age group of 35-39 and 40-44 years emerged as a notable predictor. Additionally factors such as household size and the sex of the neonate were found to be statistically significant in predicting neonatal mortality outcomes.

From the perspective of maternal-related factors the number of ever-born children a mother has and her utilization of contraception were identified as critical predictors of neonatal mortality. Furthermore the study examined immediate neonatal factors that significantly impacted survival rates. Practices such as immediate breastfeeding, the occurrence of multiple births, preceding birth interval, the season of birth and whether the delivery was conducted via caesarean section all emerged as statistically significant predictors of neonatal mortality. These findings underscore the complexity of factors influencing neonatal health and highlight the need for targeted interventions to improve survival rates among this vulnerable population.

5.2 Recommendations

Based on these findings several recommendations can be made for policy makers families and healthcare providers in order to reduce neonatal mortality rates. Firstly special attention should be given to the accessibility and quality of delivery services as the highest rate of neonatal deaths occurs on the day of delivery. This includes ensuring that pregnant women have access to proper medical care and facilities during childbirth. Secondly promoting family planning services is essential in reducing neonatal mortality rates especially for women with high parity or short preceding birth intervals. Reproductive health programs should prioritize educating communities about modern contraceptive methods to help prevent unintended pregnancies and subsequent neonatal deaths.

Additionally improving antenatal care services is crucial in providing effective lactation support and counseling as well as enhancing postnatal care to encourage immediate breastfeeding within one hour post-delivery. This not only benefits the newborn's health but also helps in establishing a strong bond between mother and child.

Lastly maternal health care for mothers over 40 years of age should receive special focus as older mothers may face additional health risks that could impact the well-being of their newborns. By implementing these recommendations policymakers families and healthcare providers can work together to improve neonatal outcomes and ensure the health and safety of both mothers and babies.

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APPENDIX

Table 10A. Results of preliminary Cox-Proportional hazard model

Covariates	**CHR**	**SE**	**Wald (χ^2)**	**Sig.**	**LR(Sig)**	**-2L**
Region			8.94		0.4428	-1239.93
Tigray (Ref.)	1					
Afar	2.379	2.119	0.97	0.331		
Amhara	3.086	1.731	2.01	0.045*		
Oromia	2.995	1.637	2.01	0.045*		
Somali	2.976	1.82	1.78	0.075		
Benishangul-Gumuz	5.441	4.169	2.21	0.027*		
S.N.N.P	2.163	1.239	1.35	0.178		
Gambela	3.082	4.817	0.72	0.471		
Harari	2.211	4.332	0.40	0.686		
Diredawa	2.998	4.104	0.80	0.422		
Age of mother			33.35		0.000***	1227.72
25 – 29 (Ref.)	1					
15 – 19	2.608	0.727	3.44	0.001**		
20 – 24	1.274	0.294	1.05	0.294		
30 – 34	0.672	0.18	-1.48	0.138		
35 – 39	.467	.163	-2.18	0.029*		
40 – 44	1.984	.536	2.53	0.011*		
45 - 49	1.562	.795	0.88	0.381		
Religion of mother			8.263		0.041	-1240.27
Orthodox (Reference)	1					
Muslim	1.423	0.27	1.86	0.063		
Protestant	0.874	0.21	-0.56	0.575		
Others	0.432	0.375	-0.97	0.334		

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Household size			82.053		0.000***	-1203.3713
Small (<4) (Reference)	1					
Medium (4-6)	0.186	0.035	-8.82	0.000***		
Large (6+)	0.173	0.036	-8.44	0.000***		
Household wealth			0.54		0.7642	-1244.13
Low (Reference)	1					
Medium	1.15	0.227	0.71	0.478		
High	1.089	0.227	0.41	0.684		
Mother's marital status			4.17		0.041*	-1242.31
Unmarried	1					
Married	0.516	0.153	-2.23	0.025*		
Education status			2.64		0.2677	-1243.08
No education (Reference)	1					
Primary education	1.314	0.224	1.60	0.941		
Secondary and above	0.989	0.367	-0.03	0.478		
Sex of the neonate			10.75		0.0010**	-1239.02
Male (Reference)	1					
Female	0.577	0.099	-3.21	0.001**		
Parity			2.97		0.0849	-1242.91
Prime Para (Reference)	1					
Multiparous	0.753	0.173	-1.24	0.217		
Grand Multiparous	0.651	0.154	-1.81	0.07		
Age at first birth			0.02		0.889	-1244.39
<18 years (Reference)	1					
=>18 years	0.980	0.160	-0.14	0.889		

Immediate breastfeeding			46.22		0.000***	-1221.29
Yes (Reference)	1					
No	3.234	0.597	6.35	0.000***		
Contraceptive use			5.03		0.025*	-1241.88
Yes (Reference)	1					
No	.672	0.122	-2.18	0.029*		
Multiple birth			13.58		0.000***	-1237.61
Single (Reference)						
Twin	1					
	3.771	1.139	4.39	0.000***		
Birth order	0.944	0.032	-1.69	0.091	0.883	1242.90
Birth interval			32.20		0.000***	-1228.29
<2 years (Ref)	1					
>= 2 years	0.394	0.079	-4.67	0.000***		
First birth	1.009	0.211	0.04	0.965		
Birth season			8.82		0.032*	-1239.99
Spring (Reference)	1					
Summer	0.614	0.134	-2.23	0.026*		
Autumn	0.806	0.168	-1.03	0.302		
Winter	0.528	0.134	-2.51	0.012*		
Delivery place			1.480		0.224	-1243.66
Home (Reference)	1					
Institution	1.222	0.201	1.22	0.222		
Skilled assistance delivery			0.806		0.369	-1243.99
Yes (Reference)	1					
No	.863	0.142	-0.90	.368		
Birth by caesarean section			9.441		0.002**	-1239.6775
Yes (Reference)	1					
No	2.646	0.737	3.49	0.000***		

Source of drinking water			1.78		0.182	-1243.51
Unimproved (Reference)	1					
Improved	1.253	0.213	1.32	0.186		
Clean cooking fuel			1.15		0.284	-1243.82
No (Reference)	1					
Yes	0.167	.393	-0.76	0.447		
Toilet facility			0.00		0.966	-1244.40
Yes (Reference)	1					
No	0.993	0.166	-0.04	.966		

Log likelihood of the empty model is -1244.4, Statistical significance level is denoted by * for p-value<0.05, ** for p-value<0.01, *** for p-value<0