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ANALYZING NEONATAL TRENDS IN KENYA

GIDEON N MANGUYIO
DEPARTMENT OF MATHEMATICS AND PHYSICAL SCIENCES DEPARTMENT
MAASAI MARA UNIVERSITY, KENYA
Manguyiog@gmail.com

OMONDI JOSEPH OUNO
DEPARTMENT OF MATHEMATICS AND PHYSICAL SCIENCES DEPARTMENT
MAASAI MARA UNIVERSITY, KENYA

CORNELIUS NYAKUNDI OMWANDO
DEPARTMENT OF MATHEMATICS AND PHYSICAL SCIENCES DEPARTMENT
MAASAI MARA UNIVERSITY, KENYA

Abstract

This study paper aims to model and establish the survival probabilities and hazard rates of neonates using the survival and hazard functions respectively. Neonatal mortality is defined as death of newborns within the first month of life. Despite advances in neonatal care, neonatal mortality remains a significant public health challenge in many low- and middle-income countries making the Sustainable Development Goal 3 difficult to attain by the year 2030.In Kenya the rate has been declining and increasing over the years, indicating much uncertainty in the achievement of this SDG goal of 12 deaths per1000 livebirths by 2030 (KDHS,2022). The study will help researchers and policy makers on understanding the trends and distribution of neonates risks in Kenya and help strengthen health systems and improve data collection. It will also enhance allocation of resources for newborn care services effectively which will translate to increase survival of newborns.

Keywords: Child mortality Neonates, survival probability, hazard ratio, Censoring, Time to event

Introduction

Survival analysis is one of the most important branches of statistics. (UN IGME,2021) it is much applicable in the field of health especially in regards to child mortality. This analysis is used to study the time until an event occurs, such as death of newborns. In the context of neonatal mortality, survival analysis helps estimate the probability of survival over time and identify risk factors influencing early deaths. (Tamir, T.T.2024) classified neonatal mortality data as a time to event data. Tamir defined time to event data as data in which subjects/newborns are followed from a clearly defined starting time until they experience the event death. For example, any death experienced between the 1st day to the 31st day of neonatal is treated as an event occurrence. Neonatal mortality is therefore defined as death of newborns within a period of one month from the time of birth. The newborns in Neonatal Mortality are referred to as Neonates about whom our study is based on. (Lawn, J.E., et al, 2014) Child Mortality is made up of Neonatal Mortality, Infant Mortality and Under-Five Mortality. Infant Mortality is deaths of newborns within a period of one year. The newborns in this case are referred as Infants. Finally, Under-Five Child Mortality is defined as deaths of children occurring between the first birthday to the fifth birth day. Child Mortality is classified as death between birth to the fifth birthday. Therefore, Neonatal Mortality constitute Child Mortality which is a major concern of the Sustainable Development Goals(SDG). If newborns are taken care of and their deaths are averted, this will automatically reduce the general rate of Child Mortality. This study will focus mainly on survival of neonates in Kenya.

(Collett ,2015) for researchers to understand the general trend of survival data, they have to specify their distributions. To analyze time-to-event data, parametric, semiparametric and nonparametric approaches can be used. In parametric and nonparametric cases one has to identify and specify which distribution do subjects of study follow. (Cox,1972) for semiparametric case like the Cox proportional hazard model one does not require to make assumption on the hazard function. In parametric where the exponential model is adopted the researchers obtains estimates which are unrealistic since this model assumes a constant hazard.

Censoring happens ultimately when the result of the study like in our case death has not been observed for some newborns. (Hosmer and Lemeshow, 1999) there are a few reasons as to why a newborn is censored. One of the reason is right censoring. right censoring occurs for example when a newborn or subject of interest relocated to a different area, and the only information a researcher has is during his or her first recruitment into the study. Another scenario of right censoring is when the baby or newborn continue living without death being observed at the end of the study period where 'death' of the baby is an event. Another form of censoring is Left censoring. Left censoring is experienced when the subjects of study in our case, the baby dies before the start or commencement of the intended research. We also have interval censoring but our main focus is right censoring. Interval censoring occurs for example, if a study records neonatal deaths weekly check-ins would be interval-censored because the precise time of death is unknown but falls within the observed interval.

In this study we will mainly concentrate on Neonatal Mortality which constitute part of Child Mortality only within Kenya. The survival time variable will be days for Neonatal Mortality Rate, months for Infant Mortality Rate and Years for Under-Five Child Mortality. The consumer of this result will mainly be those implementing the SDG 3, in our instance the Kenyan Government and UN Agencies.

Materials and Methods

In this chapter we intend to discuss functions, probabilities, ratios and models that will be relevant in data analysis. Survivor probability, Hazard ratio and Cumulative hazard ratio are highly essential in neonatal analysis.

The survival probability

The survival probability is an important topic in neonatal mortality analysis when researchers wish to study the survival of newborns. (Klein & Moeschberger,2003) survival probability

provides the probability that an event of interest such as newborn's death in neonatal mortality at a specific point in time (t) has happened. This survival probability will analyze the exact time a newborn will live past. We denote the survival probability in this study as $S(t)$.

The hazard and cumulative hazard ratios

We refer hazard ratio to as the force of mortality or instantaneous death rate or instantaneous failure rate or age-specific failure rate. It is defined as the instantaneous risk of death of a newborn happening within a very short time frame. It is not a probability but rather a ratio. On the other hand, we denote Cumulative hazard ratio as (Ht). $H(t)$ is a related ratio to the hazard ratio $h(t)$. It provides the total accumulated amount of risks to time t. Both $h(t)$ and $H(t)$ ratios can be represented mathematically as follows;

$$H(t) = \int_0^t h(t)\,dt \qquad (1)$$

We relate survival and the hazard functions as follows;

The hazard function $h(t)$ is the probability of an event occurring during a very short time interval between t and $t + \delta t$ given the newborn has lived until time "t" (that is, $P(t < T \leq t+\delta t/T > t)$. In other words, $P(t < T \leq t+\delta t/T > t)$ is the probability of a newborn dying in the next few seconds given that he or she is alive now.

$$h(t) = \frac{g(t)}{S(t)} \qquad (2)$$

where g(t) is probability of surviving up to time t and $S(t)$ is the probability of surviving beyond time t (Collett,2015).

and when we apply the chain rule for differentiation, we get;

$$h(t) = \frac{d}{dt}\big(1 - S(t)\big).\frac{1}{S(t)} \qquad (3)$$

or $h(t) = -\frac{d}{dt}S(t).\frac{1}{S(t)}$ (4)

We can further simplify equation 4 to give the negative natural logarithm below;

$$h(t) = -\frac{d}{dt}\ In\, S(t) \qquad (5)$$

We relate cumulative hazard ratio and survival probability as follows:

(Klein and Moeschberge,2003) we obtain the Cumulative hazard function $H(t)$ by integrating the hazard function in equation over the range of t. Mathematically it follows;

$$\int_0^t h(t) = \int_0^t -\frac{d}{dt}[\ln\big(S(t)\big)] \qquad (6)$$

Or $H(t) = -\ln(S(t))$ (7)

The cumulative hazard ratio $H(t)$ given in equation (7) above is the negative logarithm of survival probability at time t. From the newborn survival data, we can estimate the above hazard ratio and survival probabilities estimates using the relationships above.

Results and Discussions of Neonates Survival Trends

In this study a set of 2022 KDHS data was used. The data is publicly available on KENADA (Kenya National Data Archive) platform controlled by KNBS in their website. SPSS software was used to analyze the data. In table 1 below, we give a summary of distribution of deaths within 31 days after birth and survival possibility each day. For example, if N represents the total number of newborns that day and also if E also represents the number of deaths on the same day, then N-E=C where C is the number of censored newborns (that is, the newborns our study has no information about whether survived or relocated elsewhere).

We also present in the table the percentage of censored newborns as follows;

$$percentage\ no\ of\ censored\ newborns = \frac{C}{N} \times 100\% \qquad (8)$$

CASE PROCESSING SUMMARY OF NEWBORNS

	Total		Censored

Day of birth	N	No of Events E	C	Percent
1	251	91	160	63.7%
2	214	62	152	71.0%

3	139	37	102	73.4%
4	143	35	108	75.5%
5	227	74	153	67.4%
6	146	36	110	75.3%
7	151	41	110	72.8%
8	155	49	106	68.4%
9	107	34	73	68.2%
10	197	51	146	74.1%
11	101	35	66	65.3%
12	216	48	168	77.8%
13	137	43	94	68.6%
14	122	39	83	68.0%
15	232	62	170	73.3%
16	128	31	97	75.8%
17	98	21	77	78.6%
18	145	39	106	73.1%
19	105	26	79	75.2%
20	196	53	143	73.0%
21	93	31	62	66.7%
22	93	33	60	64.5%
23	127	36	91	71.7%
24	94	24	70	74.5%
25	144	31	113	78.5%
26	87	27	60	69.0%
27	101	29	72	71.3%
28	104	26	78	75.0%
29	70	21	49	70.0%
30	80	20	60	75.0%
31	51	16	35	68.6%
Overall	4254	1201	3053	71.8%

Table 1 Case processing summary

From table 1, we can deduce that the overall sample size of newborns in the study was 4254.Out of this total number, the number of events denoted by (E), (that is, the number of newborn deaths that occurred is 1201) and the proportion of those censored was 71.8%, meaning nearly 3 in 4 children in the sample survived past the neonatal period. This is interpreted to mean nearly a quarter of the newborns are at risk of death. This implies there are possibilities of lack of inadequate medical facilities particularly in rural areas or there is a possibility of negligence of parents to take their newborns to clinics regularly or poor nutrition care and so on. Daily trends show that the number of children per day ranges from 51 on the last day that is 31^{St} to 251 on the 1^{st} day. Also the table displays the mortality patterns whereby the first few days of life show the highest risk for neonatal deaths which gradually decline in mortality risk as days' progress. In summary deaths still occur on later days though less frequently highlighting the need for continuous care throughout the neonatal period. The data reveals that majority of neonatal deaths occur the first week of life, especially on day 1, which alone accounts for the highest proportion of deaths. As days progress, the survival rate increases, indicating improved survival with age. Overall,71.8% of the children in the dataset survived beyond the observation window, emphasizing both the importance of early intervention and effectiveness of ongoing neonatal care.

NEONATAL MORTALITY DISTRIBUTION AND TREND

In figure 1, the study gives the pictorial trend of newborn deaths within the neonatal period. It is expected to show a linear trend of deaths from the first day of birth to the last day of the neonatal period.

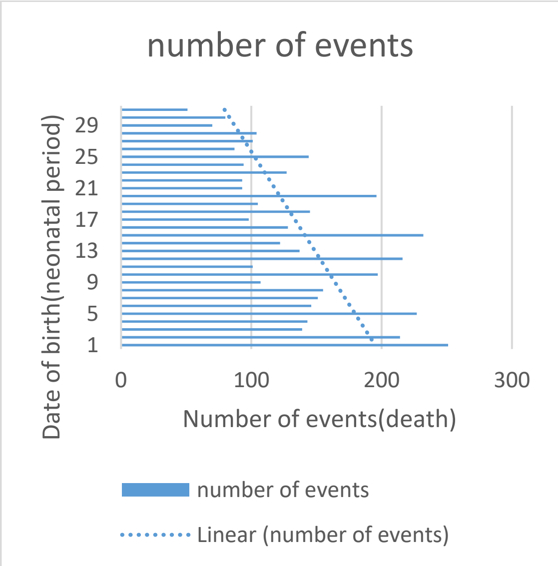

Fig 1 Neonatal Mortality Distribution Trend

Figure 1 above illustrates the distribution of neonatal deaths by date of birth, within the first month of life. The horizontal axis represents the number of events(deaths) ranging from 0 to 251 while the vertical axis represents the dates of birth within the neonatal period spanning from day 1 to day 31. The horizontal bars are the number of events or deaths for a specific date of birth. The lengths vary, suggesting that some dates had higher rates of neonatal deaths and from the graph we notice existence of spikes. This can be attributed to a possibility of premature births or infections inherited from the mother or birth complications or congenital anomalies and so on. Finally, the dotted trend line shows a general linear trend across the dates of birth, offering insight into the overall pattern of events. The general trend displayed in the graph suggest that neonatal deaths fluctuate across the different dates of birth within the first month of life. The dotted trend line shows a gradual decline, indicating that the number of deaths decrease as the day's progress. For instance, on day one there were 251 deaths, on day 16th (Mid Neonatal period) there were 125 deaths and finally on day 31 (that is, late neonatal period) had 51 deaths.

SURVIVAL PROBABILITIES FOR NEONATES

Fig 2 below is intended to display the survival probabilities of newborns from our data and that the trajectory of survival of newborns starts at a probability of 1 showing that all newborns survive at birth with this probability decreasing as time progresses according to Kaplan-Meir in 1958.

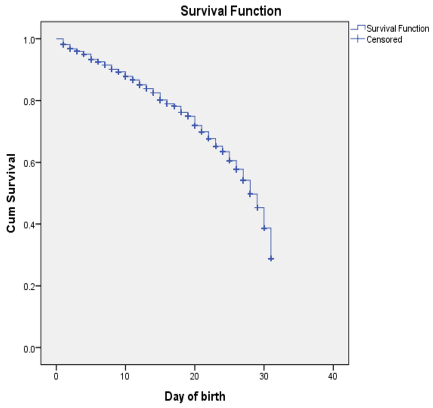

Fig 2 Survival probabilities for neonates

The fig 2 above is a representation of the cumulative probability of newborns survival over time from day 1 to day 31. The vertical axis represents cumulative survival probabilities, starting at 1.0(100%survival) and decreasing gradually over time. The blue line reflects the survival probability, which begins at 1.0 and decreases as the days progress indicating a gradual decline in survival time or probabilities. Noticeable drops occur from day 10 onwards reflecting critical days when survival chances decrease more sharply. This is because of possible onset of infections or complications from congenital conditions or inadequate postnatal care or exhaustion of initial nutrients reserves or emergence of environmental stressors. The crosses on the graph represent censored newborns whom we do not have information about. Similarly, the trend of censored newborns decreases sharply from day 10 showing a possible increase in improved medical interventions or possible improved record keeping or automation of systems or high refined data or high accuracy of record keeping. This visualization is useful for understanding the survival dynamics of newborns and identifying potential intervention periods.

CUMULATIVE HAZARD CURVE FOR NEONATES

In figure 3 below, the study intends to show that the cumulative hazard function for neonates under study from our data increases as time progresses as suggested by Kaplan and Meir in 1958.

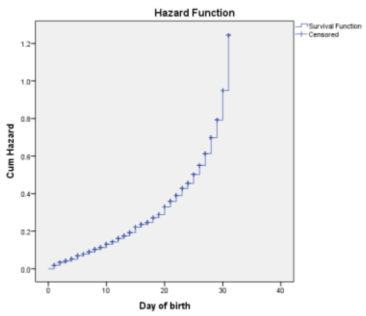

Fig 3 Cumulative Hazard function for neonates

The cumulative hazard function curve above represents the proportion of the neonate or newborns who have died from day 1 to day 31. For instance, in day 1 the ratio is 0.03, day 10 it is about 0.18 and soon. This implies that as time progresses the risk of death increases. It also assumes that by day 31, all neonates shall have perished. The curve begins near the origin and rises steadily, reflecting an increase in cumulative hazard rates as days' progress. There is a faster increase in the hazard ratios after day 20, and a sharp rise after day 30. indicating heightened risk during this period. Censored data points are marked by crosses along the curve, which indicate instances where data collections for specific days was incomplete or limited. The graph is particularly useful for analyzing how risk of neonatal deaths accumulates over time and identifying critical periods where interventions could be prioritized.

SURVIVAL PROBABILITIES FOR NEONATES BY GENDER

The figure 4 below displays survival probabilities of newborns by gender. The curve trajectory starts from 1 that is 100% survival and reduces as time progresses as suggested by Kaplan and Meir in 1958

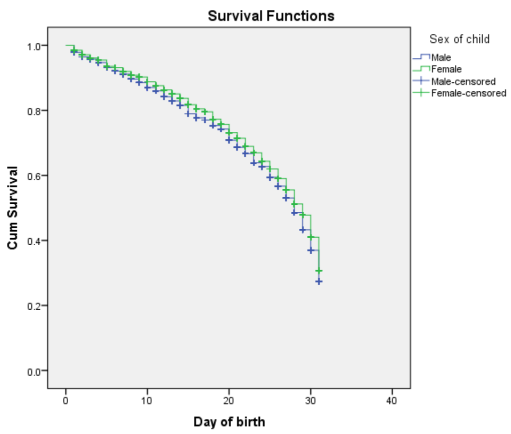

Fig 4 Survival probabilities for Neonates by Gender

The fig 4 above titled "Survival Function" depicts cumulative survival probabilities over time (0 to 31 days) for neonates by gender. The probability of survival for neonates by gender shows a general decline for both gender. For instance, on day 20 the probability of survival is about 0.68 for male neonates and for female neonates it is 0.7. On day 31, the probability of survival for male neonates is 0.28 and for female it is 0.3. This shows that survival probabilities for both gender decreases with time. For female neonates the survival probabilities are higher than survival probability of the male gender. This is possibly because of the development of lungs, hormones and immune system which may be faster in female compared to male neonates.

THE HAZARD CURVES FOR NEONATES BY GENDER

In figure 5 below we show the cumulative hazard ratios for newborns by gender

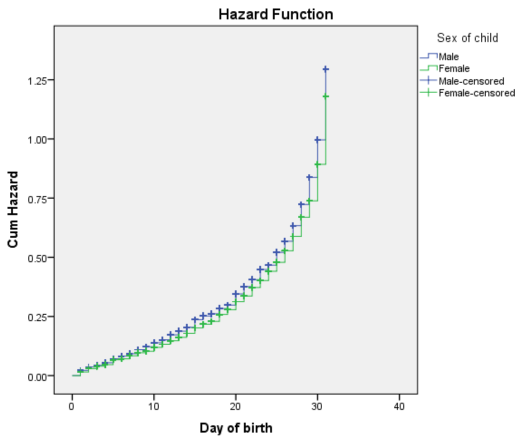

Fig 5: Hazard Ratios for Neonates by Gender

Figure 5 depicts the cumulative hazard ratio (Cum Hazard) over the first 31 days of life. The horizontal axis represents time in days, ranging from 0 to 31 days while the vertical axis represents cumulative hazard ratios ranging from 0 to 1.25. The blue line represents the cumulative hazard ratios for male newborns while the green line represents the cumulative hazard ratios for female newborns. The trajectory of both curves is the same showing that the risks for both gender increases in a similar pattern as time increases. The censored data (that is, data about which we do not have information) are marked with crosses on the lines. The cumulative hazard ratios increase for both males and females as days' progress, with a noticeable rise after 20 days. This rise is primarily due to infections and complications arising from inadequate postnatal care and delayed access to health care (KDHS,2014).

This graph is crucial for analyzing the risk patterns during the first 31 days because it offers a valuable insight for neonatal care and research. The observed trends in the cumulative hazard graph hold meaningful insights about potential risks and areas for improvement in neonatal care. The steady rise in the cumulative hazard suggests that certain factors contributing to mortality become more pronounced as time progresses

CONCLUSION

Neonatal Mortality Rate in Kenya had very minimal decline in the last 8 years, from 22/1000 live births in 2014(KDHS, 2O14) to 21/1000 live births in 2022(KDHS, 2022) making it a risk in attaining the SDG goal by 2030.

From the findings, the survival curves show the probabilities of newborns surviving beyond each day and decreases from 1. The cumulative hazard curve shows the accumulated risk increasing each day. As cumulative hazard increases, survival probability decreases, both curves mirror each other. Both curves for male and female newborns follow near-identical trajectories, suggesting no substantial difference in mortality risk between the two groups across the observed period (first 31 days). The survival curves trajectory slowly declines and the cumulative hazard curves gradually rise both smoothly. Relative risk remains consistent over time. The survival curve and cumulative hazard curve on both male and female newborns experience similarity mortality patterns in the early neonatal period; with no significant divergence in risk over time.

The shape or image mirrors on a log scale can be seen clearly as the negative natural logarithm of the survival curve, mathematically it can be shown as follows;

$H(t) = -ln\, S(t)$ or equivalently $S(t) = e^{-H(t)}$ (9)

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