Biomedical Statistics and Informatics
2023; 8(1): 1-13
http://www.sciencepublishinggroup.com/j/bsi
doi: 10.11648/j.bsi.20230801.12
ISSN: 2578-871X (Print); ISSN: 2578-8728 (Online)

Statistical Modelling and Evaluation of Determinants of Child Mortality in Nyanza, Kenya

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To cite this article:

Otieno Otieno, Mathew Kosgei, Nelson Onyango Owuor. Statistical Modelling and Evaluation of Determinants of Child Mortality in Nyanza, Kenya. *Biomedical Statistics and Informatics*. Vol. 8, No. 1, 2023, pp. 1-13. doi: 10.11648/j.bsi.20230801.12

Received: January 11, 2023; **Accepted**: February 1, 2023; **Published**: February 9, 2023

Abstract: One of the Millennium Development Goals is the reduction of infant and child mortality by two-thirds of 1990 mortality levels by 2015. Generally, significant progress has been made in reducing mortality in children under five years of age. The global under-five mortality rate declined by 59 per cent, from 93 deaths per 1,000 live births in 1990 to 38 in 2019. In Kenya, the infant mortality rate in 2021 is 32.913 deaths per 1000 live births, a 3.36 per cent decline from 2020. In 2020 it was 34.056 deaths per 1,000 live births, a drop of 3.24 per cent from the year 2019. In Kenya, Nyanza Province has the highest infant mortality rate (133 deaths per 1,000 live births) and the lowest in Central Province (44 deaths per 1,000 live births). Despite this advancement, the world still needs to achieve that Millennium Development Goal, target number four, of reducing child mortality. This study aims at identifying vital risk factors affecting child mortality in Kenya. The paper's main objective is to determine the effect of socioeconomic and demographic variables on child mortality in the presence of dependencies in clusters. We then did a logistic regression and tested the proportionality of the significant covariates. Then, performed a Stratified Cox regression model and, finally, a shared frailty model in survival analysis based on data from the Kenya Demographic and Health Survey (KDHS 2014), which was collected using questionnaires. Child mortality from the KDHS 2014 data was analyzed in an ageing period: mortality from the age of 12 months to the age of 60 months, referred to as "child mortality". The study reveals that clusters (households), maternal age at birth, preceding birth interval length and the number of births in the last five years significantly impacted child mortality.

Keywords: Frailty, Stratified Cox Model, Proportional Hazards, Correlated Survival Data

1. Introduction

Child mortality refers to the death of children under the age of five. The under-5 mortality rate (U5MR), the probability of dying before five years of age (per 1000 live births), is a key global indicator of child health [1] and one of the most important measures of global health [2].

Child mortality is essential to child health and overall national development [3]. It also reflects a country's socioeconomic development and quality of life and is used for monitoring and evaluating population, health programs and policies. In the past few decades, there has been a decline in under-five mortality in almost all countries, regardless of initial levels, socioeconomic circumstances and development strategies [4].

A high mortality rate generally signifies unmet human health needs in education, medical care, nutrition and sanitation. The desire to understand the determinants of Under 5 Child mortality (U5CM) poses a very important aspect of research. Intents to reduce under-5 mortality to at least as low as 25 deaths per 1000 live births in all countries by 2030 were previously targeted in the fourth Millennium Development Goal (MDG). Today, it appears in the third Sustainable Development Goal (SDG3) [5].

The Demographic and Health Surveys (DHS) program has been very instrumental in obtaining and disseminating accurate, nationally representative data on family planning, fertility, and maternal and child health, among other health issues. The most recent DHS survey conducted in Kenya was KDHS 2014 [6].

This study aims at identifying the determinants of Child mortality in Nyanza, Kenya. We chose a range of covariates from three different publications based on Demographic health survey data in those three countries [7-9]. Those covariates were intense in determining child mortality. In the study, we test for the proportionality assumption of those specified covariates and develop a stratified Cox model. Ultimately, build a frailty model that takes care of the dependence within clusters.

2. Methods

2.1. Data Description and Ethical Approval

This paper uses the Kenya Demographic Health Survey data *KDHS* 2014. It is the sixth Demographic and Health Survey (DHS) conducted in Kenya since 1989. KDHS is a national research undertaking conducted every five years to collect a wide range of data with a strong in- interest in indicators of reproductive health, fertility, mortality, maternal and child health, nutrition and self-reported health habits among adults [10]. It is a household sample survey data with a national representation where households are selected randomly from the Kenya National Bureau of Statistics (KNBS) sampling frame. The survey procedures, instruments and sampling methods used in the KDHS 2014 acquired ethical recommendation from the Institutional Review Board of Opinion Research Corporation (ORC) Macro International Incorporated, a health, demographic, market research and consulting company situated in New Jersey, USA. We sought official registration on the DHS website and got permission to use the KDHS 2014 data. The data was downloaded in SPSS format and constituted 1,099 variables and 20,964 observations. Using package foreign, the data was imported to R software version 4.1.2 for analysis. KDHS data is a national survey data classified into eight regions, constituting former provinces in Kenya. For this work, we analyzed data only for the Nyanza region, the region with the highest child mortality in Kenya. A set of dependent variables are chosen from the literature, given that they were profound in explaining child mortality. Survival time and status variables which are important considerations when analyzing survival data, were calculated and included in the dataset.

2.2. Ethical Approval

The study did not need any approvals because it was secondary data.

2.3. Logistic Regression Model

It is a statistical analysis (also known as logit model) frequently used in modeling and for predictive analytics. In our analytical approach, our dependent variable is categorical: (binary response). It is therefore used to understand the relationship between the dependent variable and one or more independent variables by estimating probabilities using a logistic regression equation.

The logistic regression model is given by the following equation:

$$\log\{P(x) /(1- P(x)\} = \text{logit } \{P (x)\}= \beta_0 +\beta_1 X_1 \quad (1)$$

where $P(x)$ is the probability that the dependent variable equals a case (child dies),

β_0, intercept from the linear regression,

$\beta_1 X_1$ regression coefficient multiplied by some value of predictor. The statistical significance of the association can be tested using the Wald statistic, given by $\hat{\beta}$ /SE($\hat{\beta}$)^2 $\sim \chi^2$, where $\hat{\beta}$ is the maximum likelihood estimator (MLE) of β_i and SE $\hat{\beta}$ is its associated standard error.

2.4. Kaplan-Meier Curves

Testing for Proportionality Among Covariates

Testing hypotheses:

Ho: They (covariates) are proportional.

Hi: They (covariates) are non-proportional.

We used Schoenfeld test to test for the proportionality of hazards which is a key assumption.

2.5. Stratified Cox Regression Model

The survival model used in many fields is the Cox model or Cox proportional hazard (Cox PH) model. Cox [11] and Cox Oakes [12] developed the model to predict the hazard rate of an object with covariates at risk. These covariates potentially influence survival-time (time-to-event), that is, until a child dies. The Cox model assumes that the risk level of an individual is proportional at all times, known as Cox proportional hazard [13]. Therefore, the risk comparison in the Cox model is assumed to be constant and independent with respect to (w.r.t.) time.

We propose to use a stratified Cox regression model (with and without interaction) and extended Cox regression models to take care of non-proportional hazards [14]. The stratified Cox regression, which is a modification of the Cox regression model, works by not including covariates that do not satisfy the proportional hazards assumption in the model. The interaction and no-interaction models are defined in the context of the stratified Cox regression model.

No - interaction model

Let k covariates fail to satisfy the proportional hazards assumption, and p covariates satisfy the proportional hazards assumption. The covariates not satisfying the proportional hazards assumption denoted by $Z_1, Z_2, \dots, Z_k$ and covariates satisfying the proportional indicated by $X_1, X_2, \dots, X_p$.To form the stratified Cox regression model, a new variable is defined from z and denoted by z∗. The stratification variable z∗ has k∗ categories, where k∗ is the total number of combinations (strata) formed after categorizing each of z's.

$$h_g(t, x) = h_{0g}(t)\exp[\beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p],\ g = 1, 2, \dots k*,$$

where the subscript g represents the strata. The strata are the different categorizations of the stratum variable. The variable z is not implicitly included in the model, whereas the x's which are assumed to satisfy the proportional hazards assumption are included in the model. The baseline hazard function, $h_{0g}(t)$, is different for each stratum. Since the coefficients of the x 's is the same for each stratum, the hazard ratios are same for each stratum. To obtain estimates of the regression coefficients, a likelihood function L that is obtained by multiplying together the likelihood functions for each stratum is maximized.

The general form of the Cox regression model is

$$h(t|X) = h_0(t)exp(X\beta) \quad (2)$$

where

h_0= baseline hazard function;

β =a vector of coefficient of the predictors;

X=a vector of covariates;

Model analysis and deviance.

A test of the overall statistical significance of the model is given under the "model analysis" option. Here the likelihood chi-square statistic is calculated by comparing the deviance (-2 * log-likelihood) of the model, with all of the covariates being specified, against the model with all covariates dropped. The contribution of covariates to the model can be assessed from the significance test given with each coefficient in the main output; this assumes a reasonably large sample size.

2.6. Frailty Model

The frailty approach is a statistical modelling concept which aims to account for heterogeneity caused by unmeasured covariates. In statistical terms, a frailty model is a random effect model for time-to-event data. The random effect (the frailty) has a multiplicative effect on the baseline hazard function [15]. The aim here is to account for heterogeneity caused by unmeasured covariates. In the univariate frailty model, the hazard of an individual with frailty Z is specified a

$$h_{ij}(t|X_{ij}, Z_j) = h_0(t)\exp(X_{ij}\beta)Z_j \quad (3)$$

where

ij =indicates cluster $j = 1,2,...,n_i$; $i=1,...,N$;

h_0= unspecified baseline hazard function;

Z_j = frailty term for cluster j;

β =a vector of coefficient of the predictors Assumption.

Independence is assumed across clusters but observations within cluster are possibly correlated.

3. Results

3.1. Descriptive Statistics

In Table 1, children who died in Nyanza were still high even though comparatively those who survive account for 2757(94.2%). This imply that 169(5.8%) died and that should be a matter of concern and should be mitigated to re- duce it further.

Table 1. *Child is alive in Nyanza.*

Child alive	Frequency	Percentage
No	169	0.058
Yes	2757	0.942
Total	2926	

In Table 2, majority in the survey resided in the rural areas of Nyanza province with 2014(69%) While the rest are in the urban areas of Nyanza 912(31%).

Table 2. *Place of residence.*

	Frequency	Percentage
Urban	912	0.311
Rural	2014	0.689
Total	2926	

In Table 3, even though modern techniques of family planning in Nyanza seem to have been preferred or were being used with 1583(54%). There was still a big portion who either did not use any method 1284(43.8%). Traditional methods were also still being used though with a smaller number of 54(1.8%).

Table 3. *Contraceptives/Family planing methods.*

	Frequency	Percentage
No Method	1284	0.438
Traditional Method	54	0.018
Modern Method	1588	0.542
Total	2926	

In Table 4, the distribution of children born in Nyanza province by gender. The numbers of males were slightly higher with 1485(50.75%) as compared to their female counterparts with 1441(49.25%).

Table 4. *Gender of children.*

Frequency	Percentage	
Male	1485	50.75
Female	1441	49.25
Total	2926	

In Table 5, below depicts that female children survived more than males with 76(45%) and 93(55%) respectively. On the contrary, the number of males 1392(50.5%) who survived were slightly more than their females 1365(49.5%).

Table 5. *Child alive against sex of child.*

	Sex child		
Child alive	**Male**	**Female**	**Total**
No	93	76	169
	55%	45%	100%
Yes	1392	1365	2757
	50.50%	49.50%	100%
Total	1485	1441	2926
	50.80%	49.20%	100%
$\chi^2 = 1.138$	df=1	$\psi = 0.021$	p=0.0286

Again, there was no association between sex of child and their survival or mortality. A Cramers V value is very small close to zero and the p-value is also greater than the level of significance used $\alpha = 0.05$.

Hypothesis tested

H_o =no association between Child is alive and Sex of child.

H_1 = there exists an association between Child is alive and

Sex of child.

In table 6, shows the duration it took before a child is born, and on average the period was 41.57 months. The maximum time was 225 and minimum of 9 months before a child birth.

Table 6. *Preceding birth interval (months).*

Min	1st Qu	Median	mean	3rdQu	Max	NA‘s
9	25	34	41.57	51	225	634

In table 7, showed the duration it took after a child is born and on average the period was 27.17 months. The maximum time was 58 months and minimum of 9 months before a child birth.

Table 7. *Succeding birth interval (months).*

min	1st Qu	Median	mean	3rdQu	Max	NA‘s
9	20	26	27.17	33	58	2120

In Table 8, almost all the families interviewed had 2274(99.7%) of no a live birth in between the births. Only 6(0.2%) had all alive children which is a very small number.

Table 8. *Live birth in between births.*

	Frequency	Percentage
No	2274	0.997
Yes	6	0.002
Total	2280	

In Table 9, the table showed that 111 households did not have children below 5 years, 1188 households had 2 children each and that 5 households had 5 children each.

Table 9. *Number of children under 5 years in household.*

Children	0	1	2	3	4	5
Households	111	1083	1188	438	101	5

In Table 10, in the last 5 years, 1358 households in Nyanza had 1 child born. 1238 households had 2 and 20 households had 4 children living with them.

Table 10. *Number of births in last 5 years.*

Children	1	2	3	4
Households	1358	1238	312	20

In Table 11, the lowest portion 33(0.011%) had no education at all while 1958(0.669%) had primary level of education.

Table 11. *Education level.*

Highest education level	Frequency	Percentage
No education	33	0.011
Primary	1958	0.669
Secondary	759	0.259
Higher	176	0.06
Total	2926	

In table 12, those with no education and lost children are only 2(1.2%) as compared to those with primary education who lost 129(76.3%) in that category. Higher education level lost 4(2.4%). On the other category, those with Primary education had the most alive children 1829(66.3%) while the no education lot had the least number of children with 31(1.1%). Again there existed an association between education level and whether the child survival. Our p-value is less than alpha used $\alpha = (0.05)$.

Table 12. *Association between Child alive against Education level.*

Highest education level					
Chid alive	**No education**	**Primary**	**Secondary**	**Higher**	**Total**
No	2	129	34	4	169
	1.20%	76.30%	20.10%	2.40%	100%
Yes	31	1829	725	172	2757
	1.10%	66.30%	26.30%	6.20%	100%
Total	33	1958	759	176	2926
	1.10%	66.90%	25.90%	6%	100%
	$\chi^2 = 8.692$	df=3	$\psi = 0.055$	p=0.023	

3.2. Logistic Regression Model

In table 13, below is an output of logistic regression aimed at depicting the association between a set of chosen variables and our outcome variable which is child is alive. So out rightly, three variable turned out to be statistically significant. The three variables are Succeeding birth interval length after a child has been born with a *p value*= 0.000338.

Other, significant variables number of children under five years of age in the same household and number of births in the last five years with *p values* $=2.0*10^{-16}$ and $8.26*10^{-5}$ respectively at $\alpha = 0.05$.

A variable Sex of child had two levels and, in our analysis, male child is the reference categories. Therefore, female child had a higher odd of surviving by a factor of 1.4933 than their male counterparts.

Children who were born in rural area of Nyanza Province, had a smaller odd factor of 0.909 of surviving as compared to those born in the urban areas. In other terms, they are 9.06% less likely to survive as compared to those born in urban areas.

As succeeding birth interval length increased by one unit, child survival also increased by 0.0776%.

The odds of a Child being alive until the fifth birth day was higher by a factor of $3.2247*10^6$, for those who used traditional family planning or contraceptives as compared to those who did not use any method completely. Those who used modern family planning or contraceptives were 42.773% more likely to have their children alive compared to those who do not used any method who are in the reference category.

As the number of children under five years in a household increased, the chances of child surviving in that household also increased by a factor of 11.247.

When birth order increased by one level, the odds of child being alive for 5 years is increased by a factor of 5.2984.

As the number of births in the last five years increased by one, then the chances of child surviving in that household also decreased by 82.02%.

When a mother’s age at birth increased by one year, the odds of having a child alive becomes smaller by a factor of 0.9922981. Alternatively, as a mother increased age by one year, they become less likely to have their children alive by 0.77%.

Those with Primary education level had a smaller chance by a factor of 1.936745* 10^{-7} to have a child surviving upto five years compared to those with no education.

Those with Secondary education level had a smaller chance by a factor of 1.311153* 10^{-7} to have a child surviving upto five years compared to those with no education.

Those with Higher education level have a smaller chances by a factor of 4.003798* 10^{-8} to have a child surviving upto five years compared to those with no education.

The model has an AIC = 262.7 and with a complete case analysis.

Table 13. *Logistic regression.*

	Estimate	**Std.Error**	**z value**	**Pr(>| z |)**	
(Intercept)	1.46E+01	1.21E+03	0.012	0.990339	
Sex of childFemale	4.01E-01	3.58E-01	1.12	0.262762	
Preceding birth interval length	5.94E-03	9.47E-03	0.627	0.530403	
Place of residenceRural	-9.50E-02	4.17E-01	-0.228	0.819963	
Succeding birth interval length	7.47E-02	2.09E-02	3.584	0.000338	***
FP contraceptive useTraditional	1.50E+01	1.04E+03	0.014	0.988477	
FP contraceptive useModern	3.56E-01	3.60E-01	0.989	0.322747	
Number of children under 5 in HH	2.42E+00	2.83E-01	8.558	¡ 2.00E-16	***
Birth order	1.67E+00	1.62E+00	1.029	0.303476	
Number of births in last 5 years	-1.72E+00	4.36E-01	-3.937	8.26E-05	***
Maternal age at birth	-7.73E-03	6.96E-02	-0.111	0.91157	
Education levelPrimary	-1.55E+01	1.21E+03	-0.013	0.989789	
Education levelSecondary	-1.59E+01	1.21E+03	-0.013	0.989531	
Education levelHigher	-1.70E+01	1.21E+03	-0.014	0.988747	

3.3. Kaplan-Meier Curves

In figure 1 we estimate survival function without any variable.At the top left, 100% meaning none had experienced any event yet and the survival prob- abilities decrease as time increases.

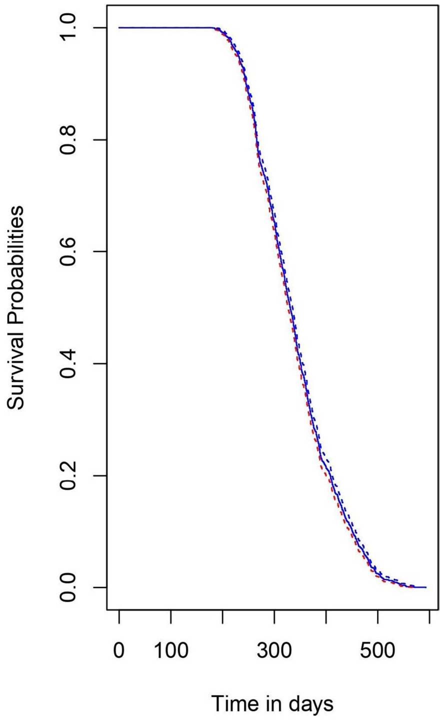

Figure 1. *Kaplan-Meier without a variable.*

In figure 2 both curves are almost the same, and both male and female children had a median survival time at approximately 330 days.

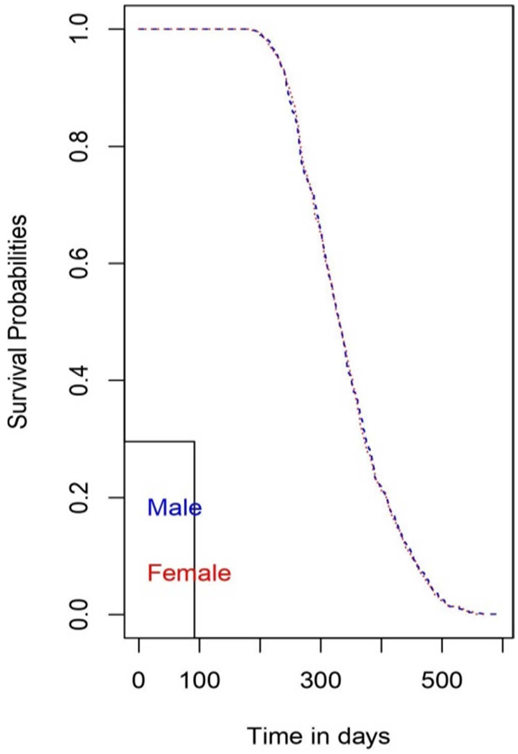

Figure 2. *Kaplan-Meier for sex of child.*

In figure 3 show the situation in terms of how survival chances were in the two places of residence that is rural and urban. Both curves begin together implying no early experiences at the start. At approximately 250 days there is a deviation from the two curves which implies that those children who reside in rural places have a slightly lower survival chances until 500 days as compared to those living in urban areas.

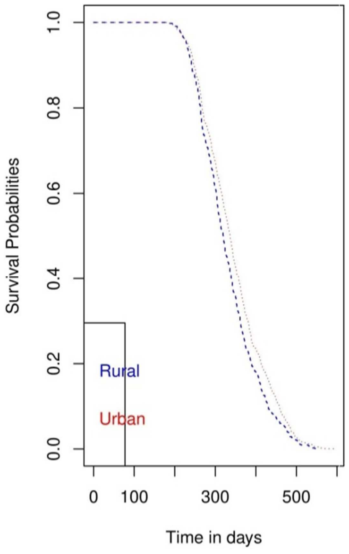

Figure 3. *Kaplan-Meier for residence.*

Log-rank test- Sex of Child

It is the most common technique to compare survival between two groups.

Testing hypotheses:

Ho: There is no survival difference between the two groups.

Hi: There is a survival difference between the two groups.

In table 14, our *p - value* = 0.8 which implies that we fail to reject our null hypothesis and infer that there is no survival difference between the males and females children at α = 0.05. Additionally, this is confirmed by figure 4, that the there was no difference or deviance between the two survival curves. In fact, it just appeared to be one survival curve and with a medium value of approximately 330 days.

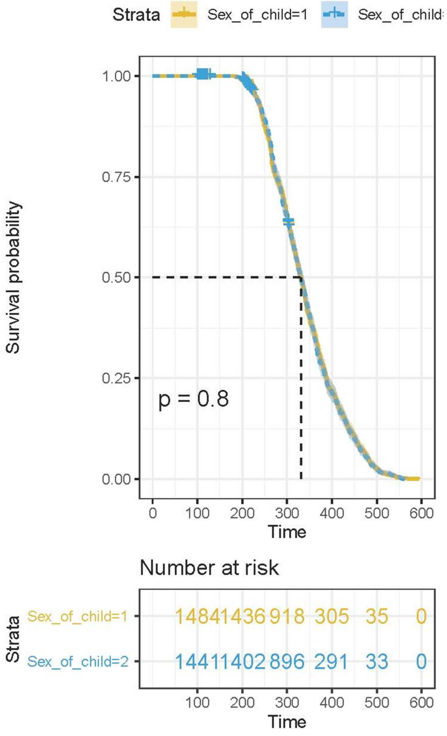

Figure 4. *Kaplan Meier for Sex of Child.*

Table 14. *Log rank by Sex of child.*

	N	Observed	Expected	(O-E)^2/E	(O-E)^2/V
Male	1484	1392	1399	0.0325	0.0668
Female	1441	1365	1358	0.0335	0.0668
Chisq=0.1	df=1	p=0.8			

Log-rank test- Place of residence

Based on the same hypothesis above, table 15 gave the result with a p – value = 4x10^{-6} showing that there was a statistical significance and that there exists a survival difference between the rural and urban. Prospects of better survival were in urban areas as compared to rural areas where children were born.

Table 15. *Log rank by place of residence.*

	N	Observed	Expected	(O-E)^2/E	(O-E)^2/V
Urban	911	869	761	15.18	21.3
Rural	2014	1888	1996	5.79	21.3
Chisq=21.3	df=1	p=4e-06			

In figure 5, gave a visual expression of how survivorship is by the variable place of residence i.e. either rural or urban areas where those children were born.

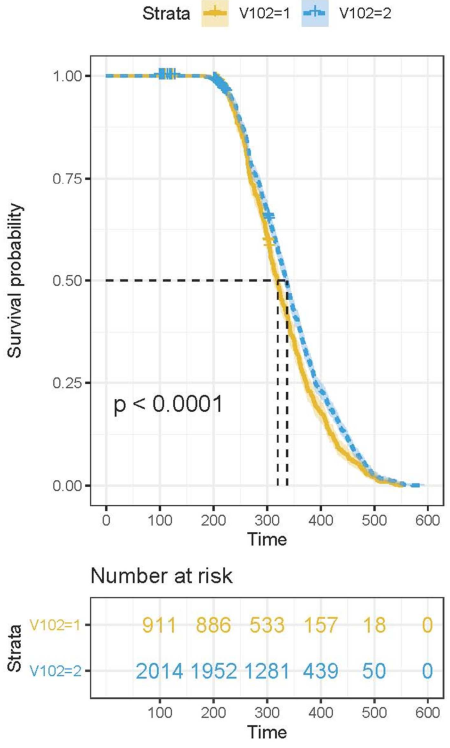

Figure 5. *Plot of survival in urban and rural areas.*

In table 16, gave just an estimate of survival without any particular variable. We had time variable measured in days, n. risk are the number of children at risk of death, survival probabilities as time increases. Others are standard errors and confidence interval namely, lower and upper.

At 180 days there were 2862 children at risk and only 1 died. The probability of surviving up to 180 days was (0.999651%) with a very close 95% confidence interval (0.999, 1.00).

Table 16. *Kaplan Meier for survival without a variable.*

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
180	2862	1	0.999651	0.000349	9.99E-01	1
184	2861	2	0.998952	0.000605	9.98E-01	1
185	2859	2	0.998253	0.000781	9.97E-01	0.99978
186	2857	1	0.997904	0.000855	9.96E-01	0.99958
188	2856	1	0.997554	0.000923	9.96E-01	0.99937
191	2855	1	0.997205	0.000987	9.95E-01	0.99914
192	2854	1	0.996855	0.001047	9.95E-01	0.99891
193	2853	1	0.996506	0.001103	9.94E-01	0.99867
194	2852	4	0.995108	0.001304	9.93E-01	0.99767
195	2848	1	0.994759	0.00135	9.92E-01	0.99741
196	2847	2	0.99406	0.001436	9.91E-01	0.99688
197	2845	3	0.993012	0.001557	9.90E-01	0.99607
198	2842	2	0.992313	0.001633	9.89E-01	0.99552
199	2840	2	0.991614	0.001705	9.88E-01	0.99496
201	2838	1	0.991265	0.001739	9.88E-01	0.99468
202	2829	2	0.990564	0.001807	9.87E-01	0.99411
203	2818	2	0.989861	0.001873	9.86E-01	0.99354
204	2805	4	0.988449	0.001999	9.85E-01	0.99238
205	2793	5	0.98668	0.002146	9.82E-01	0.9909
206	2783	4	0.985262	0.002257	9.81E-01	0.9897
207	2771	1	0.984906	0.002284	9.80E-01	0.98939
208	2765	2	0.984194	0.002338	9.80E-01	0.98879
209	2759	3	0.983124	0.002415	9.78E-01	0.98787
210	2750	1	0.982766	0.002441	9.78E-01	0.98756
211	2749	2	0.982051	0.002491	9.77E-01	0.98695
212	2746	6	0.979905	0.002635	9.75E-01	0.98508
213	2732	8	0.977036	0.002816	9.72E-01	0.98257
214	2723	1	0.976677	0.002838	9.71E-01	0.98225
215	2720	4	0.975241	0.002923	9.70E-01	0.98099
216	2714	3	0.974163	0.002985	9.68E-01	0.98003
217	2710	10	0.970568	0.003183	9.64E-01	0.97683
218	2697	4	0.969129	0.003259	9.63E-01	0.97554
219	2690	5	0.967327	0.003351	9.61E-01	0.97392
220	2684	4	0.965886	0.003423	9.59E-01	0.97262
221	2678	3	0.964804	0.003475	9.58E-01	0.97164
222	2674	3	0.963721	0.003527	9.57E-01	0.97066
223	2670	4	0.962277	0.003595	9.55E-01	0.96935
224	2666	6	0.960112	0.003694	9.53E-01	0.96738
225	2659	4	0.958668	0.003758	9.51E-01	0.96606
226	2655	2	0.957945	0.00379	9.51E-01	0.9654
227	2653	2	0.957223	0.003821	9.50E-01	0.96474
228	2651	6	0.955057	0.003914	9.47E-01	0.96276
229	2645	7	0.952529	0.004018	9.45E-01	0.96044
230	2638	8	0.949641	0.004134	9.42E-01	0.95778
231	2630	3	0.948557	0.004176	9.40E-01	0.95678
232	2627	8	0.945669	0.004287	9.37E-01	0.95411
233	2619	15	0.940252	0.004484	9.32E-01	0.94908
234	2604	4	0.938808	0.004535	9.30E-01	0.94774
235	2600	9	0.935558	0.004647	9.26E-01	0.94471
236	2591	3	0.934475	0.004684	9.25E-01	0.9437
237	2588	7	0.931948	0.004767	9.23E-01	0.94134
238	2581	4	0.930503	0.004814	9.21E-01	0.93999
239	2577	4	0.929059	0.004861	9.20E-01	0.93863
240	2573	11	0.925087	0.004985	9.15E-01	0.93491
241	2562	20	0.917865	0.005201	9.08E-01	0.92812
242	2542	6	0.915699	0.005264	9.05E-01	0.92607
243	2536	25	0.906672	0.005513	8.96E-01	0.91754
244	2511	6	0.904505	0.00557	8.94E-01	0.91549
245	2505	14	0.89945	0.0057	8.88E-01	0.91069
246	2491	11	0.895478	0.0058	8.84E-01	0.90692
247	2480	5	0.893673	0.005844	8.82E-01	0.9052
248	2475	8	0.890784	0.005914	8.79E-01	0.90245
249	2467	18	0.884285	0.006066	8.72E-01	0.89625
250	2449	5	0.88248	0.006107	8.71E-01	0.89453
251	2444	10	0.878869	0.006188	8.67E-01	0.89108

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
252	2434	13	0.874175	0.00629	8.62E-01	0.88659
253	2421	13	0.869481	0.00639	8.57E-01	0.88209
254	2408	8	0.866592	0.006449	8.54E-01	0.87933
255	2400	4	0.865148	0.006479	8.53E-01	0.87794
256	2396	7	0.86262	0.00653	8.50E-01	0.87551
257	2389	15	0.857204	0.006637	8.44E-01	0.87031
258	2374	14	0.852149	0.006734	8.39E-01	0.86545
259	2360	12	0.847816	0.006815	8.35E-01	0.86128
260	2348	18	0.841316	0.006933	8.28E-01	0.85501
261	2330	18	0.834817	0.007047	8.21E-01	0.84874
262	2312	14	0.829762	0.007132	8.16E-01	0.84386
263	2298	17	0.823624	0.007233	8.10E-01	0.83792
264	2281	32	0.812069	0.007414	7.98E-01	0.82673
265	2249	22	0.804125	0.007533	7.89E-01	0.81903
266	2227	32	0.792571	0.007697	7.78E-01	0.8078
267	2195	10	0.78896	0.007746	7.74E-01	0.80429
268	2185	24	0.780294	0.00786	7.65E-01	0.79585
269	2161	17	0.774156	0.007938	7.59E-01	0.78987
270	2144	12	0.769823	0.007991	7.54E-01	0.78565
time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
271	2132	10	0.766212	0.008035	7.51E-01	0.78212
272	2122	17	0.760073	0.008108	7.44E-01	0.77613
273	2105	7	0.757546	0.008137	7.42E-01	0.77366
274	2098	7	0.755018	0.008165	7.39E-01	0.77119
275	2091	6	0.752852	0.00819	7.37E-01	0.76908
276	2085	11	0.74888	0.008234	7.33E-01	0.76519
277	2074	9	0.74563	0.008269	7.30E-01	0.76201
278	2065	8	0.742742	0.0083	7.27E-01	0.75919
279	2057	11	0.73877	0.008341	7.23E-01	0.7553
280	2046	4	0.737325	0.008356	7.21E-01	0.75389
281	2042	5	0.73552	0.008375	7.19E-01	0.75212
282	2037	12	0.731187	0.008418	7.15E-01	0.74787
283	2025	10	0.727576	0.008454	7.11E-01	0.74434
284	2015	7	0.725049	0.008478	7.09E-01	0.74186
285	2008	9	0.721799	0.008509	7.05E-01	0.73867
286	1999	16	0.716022	0.008563	6.99E-01	0.733
287	1983	10	0.712411	0.008595	6.96E-01	0.72946
288	1973	11	0.708439	0.00863	6.92E-01	0.72556
289	1962	19	0.701579	0.008689	6.85E-01	0.71882
290	1943	19	0.694718	0.008745	6.78E-01	0.71207
291	1924	17	0.68858	0.008794	6.72E-01	0.70603
292	1907	9	0.68533	0.008819	6.68E-01	0.70283
293	1898	11	0.681358	0.008849	6.64E-01	0.69892
294	1887	10	0.677747	0.008875	6.61E-01	0.69537
295	1877	8	0.674859	0.008896	6.58E-01	0.69252
296	1869	18	0.668359	0.008941	6.51E-01	0.68612
297	1851	17	0.662221	0.008982	6.45E-01	0.68006
298	1834	11	0.658249	0.009008	6.41E-01	0.67614
299	1823	9	0.654999	0.009028	6.38E-01	0.67294
300	1814	5	0.653194	0.009039	6.36E-01	0.67115
301	1809	19	0.646333	0.00908	6.29E-01	0.66438
302	1790	20	0.639112	0.009121	6.21E-01	0.65724
303	1762	12	0.634759	0.009145	6.17E-01	0.65294
304	1747	22	0.626766	0.009188	6.09E-01	0.64503
305	1722	18	0.620214	0.009221	6.02E-01	0.63855
306	1704	17	0.614026	0.00925	5.96E-01	0.63243
307	1687	7	0.611479	0.009261	5.94E-01	0.6299
308	1680	14	0.606383	0.009284	5.88E-01	0.62485
309	1666	11	0.602379	0.009301	5.84E-01	0.62089
310	1655	17	0.596192	0.009326	5.78E-01	0.61475
311	1638	13	0.59146	0.009343	5.73E-01	0.61006
312	1625	11	0.587456	0.009358	5.69E-01	0.60609
313	1614	17	0.581269	0.009379	5.63E-01	0.59994
314	1597	11	0.577265	0.009392	5.59E-01	0.59597
315	1586	17	0.571077	0.00941	5.53E-01	0.58982
316	1569	6	0.568893	0.009416	5.51E-01	0.58765

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
317	1563	9	0.565618	0.009425	5.47E-01	0.5844
318	1554	13	0.560886	0.009437	5.43E-01	0.57969
319	1541	15	0.555426	0.00945	5.37E-01	0.57426
320	1526	23	0.547055	0.009467	5.29E-01	0.56593
321	1503	12	0.542687	0.009475	5.24E-01	0.56158
322	1491	13	0.537956	0.009483	5.20E-01	0.55687
323	1478	12	0.533588	0.00949	5.15E-01	0.55252
324	1466	17	0.5274	0.009498	5.09E-01	0.54635
325	1449	15	0.521941	0.009503	5.04E-01	0.5409
326	1434	10	0.518301	0.009506	5.00E-01	0.53727
327	1424	13	0.513569	0.00951	4.95E-01	0.53255
328	1411	9	0.510293	0.009512	4.92E-01	0.52928

In table 17, gave just an estimate of survival of a male child. At 184 days there were 1451 children at risk and only 1 died. The probability of surviving upto 184 days was (0.99931%) with a very close 95% confidence interval (0.997, 1.00).

Table 17. *Survival of a Male child.*

time	n.risk	n.event	Survival	std.err	lower 95 CI	upper 95% CI
184	1451	1	0.99931	0.000689	0.997961	1
185	1450	2	0.99793	0.001192	0.995598	1
191	1448	1	0.99724	0.001376	0.994549	0.99994
193	1447	1	0.99655	0.001538	0.993543	0.99957
194	1446	3	0.99449	0.001944	0.990684	0.9983
195	1443	1	0.9938	0.002061	0.989766	0.99785
196	1442	2	0.99242	0.002277	0.987966	0.99689
197	1440	2	0.99104	0.002474	0.986204	0.9959
198	1438	1	0.99035	0.002566	0.985335	0.99539
199	1437	1	0.98966	0.002655	0.984472	0.99488
203	1425	1	0.98897	0.002743	0.983607	0.99436
204	1414	3	0.98687	0.002993	0.981022	0.99275
205	1407	2	0.98547	0.003148	0.979315	0.99166
208	1396	1	0.98476	0.003224	0.978461	0.9911
212	1386	2	0.98334	0.003373	0.976752	0.98997
213	1381	5	0.97978	0.003717	0.972521	0.98709
215	1374	1	0.97907	0.003782	0.971681	0.98651
216	1373	2	0.97764	0.003909	0.970009	0.98533
217	1371	7	0.97265	0.00432	0.964218	0.98115
218	1362	3	0.97051	0.004484	0.961757	0.97934
219	1358	2	0.96908	0.00459	0.960122	0.97812
220	1356	3	0.96693	0.004744	0.957679	0.97628
221	1351	1	0.96622	0.004794	0.956866	0.97566
222	1349	1	0.9655	0.004844	0.956054	0.97504
223	1348	1	0.96478	0.004893	0.955242	0.97442
224	1347	5	0.9612	0.00513	0.951201	0.97131
225	1341	2	0.95977	0.005222	0.94959	0.97006
226	1339	1	0.95905	0.005267	0.948786	0.96943
228	1338	5	0.95547	0.005486	0.944778	0.96628
229	1333	5	0.95189	0.005694	0.94079	0.96311
230	1328	4	0.94902	0.005855	0.937612	0.96056
231	1324	1	0.9483	0.005894	0.936819	0.95992
232	1323	4	0.94543	0.006048	0.933654	0.95736
233	1319	6	0.94113	0.00627	0.928924	0.9535
234	1313	4	0.93827	0.006413	0.925781	0.95092
235	1309	5	0.93468	0.006586	0.921864	0.94768
236	1304	3	0.93253	0.006687	0.919518	0.94573
237	1301	4	0.92967	0.006818	0.916398	0.94312
239	1297	1	0.92895	0.00685	0.915619	0.94247
240	1296	7	0.92393	0.007071	0.910176	0.93789
241	1289	12	0.91533	0.007428	0.900886	0.93001
242	1277	4	0.91246	0.007542	0.897799	0.92737
243	1273	13	0.90314	0.007895	0.887801	0.91875
244	1260	4	0.90028	0.007999	0.884734	0.91609
245	1256	8	0.89454	0.008201	0.878612	0.91076
246	1248	7	0.88953	0.008372	0.873267	0.90609
247	1241	4	0.88666	0.008467	0.870218	0.90341
248	1237	4	0.88379	0.00856	0.867173	0.90073

time	n.risk	n.event	Survival	std.err	lower 95 CI	upper 95% CI
249	1233	11	0.87591	0.008807	0.858814	0.89334
250	1222	2	0.87447	0.008851	0.857296	0.89199
251	1220	7	0.86946	0.009001	0.851991	0.88728
252	1213	7	0.86444	0.009147	0.846695	0.88255
253	1206	6	0.86014	0.009268	0.842162	0.8785
254	1200	3	0.85799	0.009328	0.839898	0.87647
255	1197	1	0.85727	0.009348	0.839144	0.87579
256	1196	4	0.8544	0.009426	0.836128	0.87308
257	1192	6	0.8501	0.00954	0.831608	0.86901
258	1186	5	0.84652	0.009634	0.827846	0.86561
259	1181	6	0.84222	0.009744	0.823336	0.86153
260	1175	6	0.83792	0.009851	0.818831	0.85745
261	1169	11	0.83003	0.010041	0.810585	0.84995
262	1158	8	0.8243	0.010174	0.804597	0.84448
263	1150	8	0.81856	0.010303	0.798617	0.83901
264	1142	18	0.80566	0.01058	0.78519	0.82667
265	1124	13	0.79634	0.010769	0.775515	0.81773
266	1111	18	0.78344	0.011015	0.762147	0.80533
267	1093	6	0.77914	0.011094	0.757698	0.80119
268	1087	10	0.77197	0.011221	0.750291	0.79428
269	1077	7	0.76696	0.011307	0.745111	0.78944
270	1070	5	0.76337	0.011367	0.741414	0.78598
271	1065	4	0.7605	0.011415	0.738458	0.78321
272	1061	6	0.7562	0.011484	0.734027	0.77905
273	1055	5	0.75262	0.011541	0.730336	0.77558
274	1050	2	0.75119	0.011564	0.728861	0.7742
275	1048	1	0.75047	0.011575	0.728123	0.7735
276	1047	4	0.7476	0.011619	0.725173	0.77073
277	1043	4	0.74474	0.011663	0.722225	0.76795
278	1039	5	0.74115	0.011716	0.718541	0.76447
279	1034	7	0.73613	0.011789	0.713387	0.75961
280	1027	2	0.7347	0.01181	0.711915	0.75822
282	1025	7	0.72968	0.01188	0.706766	0.75334
283	1018	5	0.7261	0.01193	0.70309	0.74986
284	1013	3	0.72395	0.011959	0.700885	0.74777
285	1010	2	0.72252	0.011978	0.699416	0.74638

3.4. Testing for Proportionality Among Covariates

In table 18, displays the Global p *value* < 0.05. It gives the general picture of proportional hazards violations among the variables in the model. That value is way too small suggesting the existence of one or more violations [6]. Therefore, dipping into individual performance to check if proportional hazards assumption has been met.

We have four variables namely, Preceding birth interval length with p - *value* $= 0.00384$, Source of drinking water $p -$ *value* $= 0.00012$, Type of toilet facility $p -$ *value* $= 0.0107$ and Number of births in last 5 years with a $p -$ *value* $=$ 0.04545.These covariates do not meet the assumption given that they have a $p -$ *values* < 0.05.

Table 18. *Testing for proportionality among covariates.*

	chisq	df	P
Sex of child	2.235	1	0.13489
Preceding birth interval length	8.358	1	0.00384
Education level	5.188	2	0.07473
Source of drinking water	36.844	11	0.00012
Type of toilet facility	13.122	4	0.0107
Number of children under 5 in HH	0.465	1	0.49529
Number of births in last 5 years	4.002	1	0.04545
Maternal age at birth	0.695	1	0.4046
Taught FP health worker	0.958	1	0.32764
GLOBAL	65.46	23	6.00E-06

In figure 6, Scaled Schoenfeld residuals against time. The broken lines represent a standard error band around the fit while the continuous line represents a smoothing spline fit to the plot. The line of fit is expected to stay close to the horizontal axis within the whole expanse of time, so that we can conclude that the Proportional Hazard assumption holds or not violated. In general, we have symmetry along the zero – line and have no fear for existence of influential observations in the data or outliers.

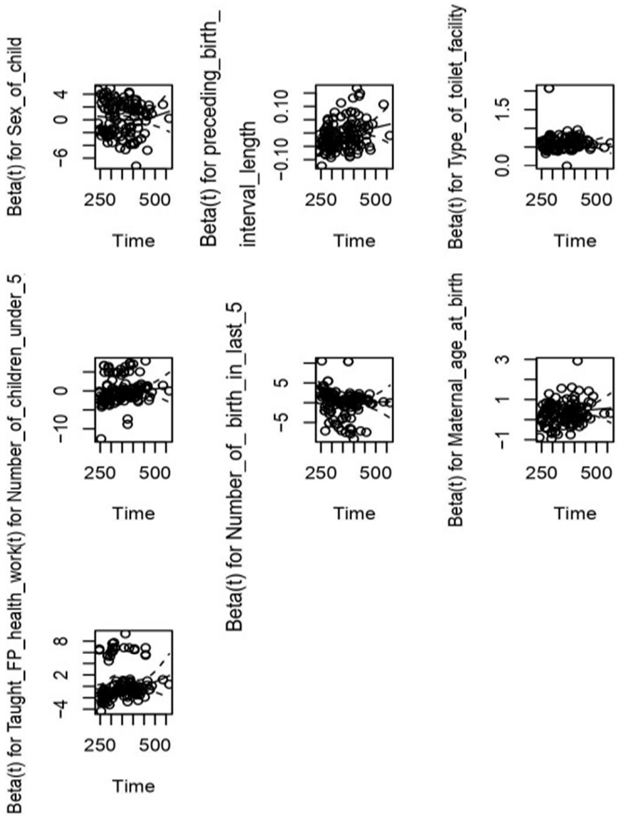

Figure 6. *Schoenfeld residuals.*

3.5. Determining the Effects of All the Variable

After a diagnostic tests on CoX PH models, the respective predictors were fitted to the Cox PH parsimonious Cox PH [16] in order to check concurrently the effect of different risk factors on survival time.

3.6. Stratified Cox Regression Model

In Table 19, exhibits the output from the Stratified Cox model with variables Higher Education *p value* = 0.00738, Number of children under 5 in HH (household) *p value*= $2.61*10^{-5}$ and Maternal age at birth *p - value* $=1.19*10^{-9}$ being statistically significant at $\alpha = 0.05$.

The odds of a Female child surviving were higher by a factor of 1.0572 as compared to the male child.

Those with Primary education were 18% less likely to have their children alive as compared to those with no education.

Those with Secondary education had a higher a higher odds factor of 2.0551 to have their children alive until the fifth birth day as compared to those with no education.

Those with Higher education had a higher odds factor of 14.0583 to have their children alive until the fifth birth day as compared to those with no education.

As the number of children under five years in a household increased by one, then the odds of survival also increased by 67.53%.

As maternal age increased by one year, then the chances of child survival decreased by 21%.

Those who were taught about family planning by health workers were 33.58% more likely to have their children survive until five years as compared to those who did were not taught by health workers.

Table 19. *Stratified Cox model.*

	Coef	**exp(coef)**	**se(coef)**	**Z**	**Pr(>| *z* |)**	
Sex of childFemale	0.05561	1.05719	0.17662	0.315	0.75286	
Education levelPrimary	-0.20644	0.81348	0.7201	-0.287	0.77436	
Education levelSecondary	0.72033	2.05511	0.7596	0.948	0.34297	
Education levelHigher	2.64321	14.05831	0.98651	2.679	0.00738	**
Number of children under 5 in HH	0.51601	1.67532	0.1227	4.205	2.61E-05	***
Maternal age at birth	-0.24131	0.7856	0.03968	-6.081	1.19E-09	***
Taught FP health workerYes	0.28953	1.3358	0.22448	1.29	0.19713	

	exp(coef)	**exp(-coef)**	**lower 0.95**	**upper 0.95**
Sex of childFemale	1.0572	0.94591	0.7479	1.4945
Education levelPrimary	0.8135	1.22929	0.1983	3.3366
Education levelSecondary	2.0551	0.48659	0.4637	9.1077
Education levelHigher	14.0583	0.07113	2.0334	97.1959
Number of children under 5 in HH	1.6753	0.5969	1.3172	2.1308
Maternal age at birth	0.7856	1.27291	0.7268	0.8491
Taught FP health workerYes	1.3358	0.74861	0.8603	2.0741

3.7. Frailty Model

In table 20, is the frailty output, four variables are statistically significant in explaining child survival. They are Frailty (Household number) with a *p value* = $4.5x10^{-7}$, Preceding birth interval length with a *p value* = 0.0058, Number of births in the last 5 years and maternal age at birth with *p values* = 0.01 and $4.9x10^{-13}$ respectively.

The odds of a Female child surviving were higher by a factor of 1.0698 as compared to the male child.

As preceding birth interval length increased by one unit, the chances of child survival decreased by a factor of 0.9828.

Those with Primary education were 19% less likely to have their children alive as compared to those with no education.

Those with Secondary education had a higher a higher odds factor of 1.6802 to have their children alive until the fifth birth day as compared to those with no education.

As the number of children under five years in a household increased by one, then the odds of child survival also increased by 1.9%.

As the number of births in last five years increased by one, then the odds of child survival also increased by 2.2728%.

As maternal age increased by one year, then the chances of child survival decreased by 39%.

Those who were taught about family planning by health workers were 16.17% more likely to have their children survive until five years as compared to those who did were not taught by health workers.

Table 20. *Shared Frailty model.*

	Coef	se(coef)	se2	Chisq	DF	p
frailty(Household number)				77.17	25.6	4.50E-07
Sex of child Female	0.06751	0.247112	0.223143	0.07	1	7.80E-01
Preceding birth interval length	-0.01738	0.006293	0.005596	7.63	1	5.80E-03
Education level Primary	-0.20885	0.872512	0.778994	0.06	1	8.10E-01
Education level Secondary	0.51892	0.978493	0.866638	0.28	1	6.00E-01
Education level Higher		0	0		1	
Number of children under 5 in HH	0.01879	0.278245	0.234417	0	1	9.50E-01
Number of births in last 5 years	0.82101	0.318641	0.253443	6.64	1	1.00E-02
Maternal age at birth	-0.47893	0.066264	0.056536	52.24	1	4.90E-13
Taught FP health workerYes	0.1499	0.337296	0.288641	0.2	1	6.60E-01

	exp(coef)	exp(-coef)	lower 0.95	upper 0.95
Sex of childFemale	1.0698	0.9347	0.6591	1.7364
Preceding birth interval length	0.9828	1.0175	0.9707	0.995
Education level Primary	0.8115	1.2323	0.1468	4.4873
Education level Secondary	1.6802	0.5952	0.2469	11.4356
Education level Higher	NA	NA	NA	NA
Number of children under 5 in HH	1.019	0.9814	0.5906	1.7579
Number of births in last 5 years	2.2728	0.44	1.2171	4.2441
Maternal age at birth	0.6194	1.6144	0.544	0.7054
Taught FP health worker Yes	1.1617	0.8608	0.5998	2.2501

4. Discussion

The study attempts to understand the determinants of child mortality using survey data from KDHS. In this case, the Kenya DHS survey 2014 dataset was used for the analysis. For this work, we analysed data for Nyanza province, only being region with the highest child mortality in Kenya.

A high mortality rate generally signifies unmet human health needs in education, medical care, nutrition and sanitation. Therefore, the aspiration to understand the determinants of Child mortality gives rise to a very important aspect of research.

Many studies have employed regression techniques to explore the determinants of U5CM. The Cox PH regression was used by [17-19].

Even though we used logistic regression and the Cox PH model, we went further. We tested for the proportionality among those covariates to ensure that the results from the Cox PH are more reliable and valid.

In our findings, we realised the following covariates; Succeeding and Preceding birth interval length, number of children under five years in the household, number of births in the last five years, Higher Education and Maternal age at birth were statistically significant in determining child mortality.

In comparison with other studies that were published, there was no significant mismatch in that findings showed that child mortality was associated with variables related to child characteristics at birth (such as age at birth), reproduction factors of the mother (such as a number of siblings born before), feeding characteristics and anthropometric measurements.

This was in line with other findings which used Cox PH regression and established that region of residence, sex of the child, type of birth (multiple), birth interval (less than 24 months after the preceding birth), and mother's education were related with an increased risk of childhood mortality before their fifth birthday [17]. Nasejje et. al., also established that factors related to mother characteristics and previous births such as the sex of the child, the sex of the head of the household, and the number of births in the past year, were significant [18]. Sreeramareddy et al., explored the effect of the mother's education, child's sex, rural/urban residence, household wealth index, region ecological zones and development [19].

In our work, we had a large sample of 2926 observations and 1132 variables which was statistically sufficient. Nevertheless, we ignored the limitation of missing cases and just used complete cases in our analysis. So imbalance in the data, if attended to, could have given us different results altogether.

Another limitation was that we did not use any scientific method to choose the covariates we worked on. That was just chosen from the literature. The study is of significance in that it will help the government; non-governmental organisations get information to guide them on how to intervene to ultimately achieve the global target on Child mortality.

Furthermore, students actively researching child mortality may fill the gap and add to the already existing bank of knowledge.

5. Conclusion

Correlated survival data arises from numerous health fields, especially where participants are in a cluster or household sharing the same prognostic factors. In this research, we have managed to present a framework for the determination of child mortality using the 2014 KDHS data from Nyanza Province in Kenya. Majorly, the framework involved checking which covariates were notable in explaining child survival. Moreover, based on this research, child mortality is associated with variables related to reproduction factors of the mother (such as the number of children under five years in the household, number of births in the last five years, succeeding and preceding birth interval length), age of the mother at birth, and higher education.

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