



Understanding the Correlates of Under-five Mortality in Sudan Using Survey Survival Models

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Authors' contributions

This work was carried out in collaboration among all authors. Author AS acquired the data. Authors DGA, AS and TZ analyzed and prepared the draft manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Under-five mortality is among the major public health problems in developing countries, the rate of which is an important factor for a country's development. For this reason, under-five mortality status is an important outcome to measure for children's health. This study uses the Cox proportional-hazards model to identify risk factors associated with under-five mortality in Sudan. This study uses the 2014 Sudan Multiple Indicator Cluster Survey (MICS) conducted by the Central Bureau of Statistics in collaboration with several national institutions. The survival Cox proportional-hazards model was used to identify factors that affect under-five child mortality in Sudan. The results show that the weight of a child at birth is positively associated with the under-five child mortality rate. Under-five children who have both small and large weights at birth are at a higher risk of dying before reaching five years. Based on demographic factors associated with under-five mortality, our analysis showed that mothers who were married at the time of the survey are most likely to have higher under-five child mortality as compared to formerly married mothers. In addition to this, that mother's age at the time of the birth is significantly associated with under-five mortality. Based on the result, the lack of

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important policies targeting the reduction of socioeconomic inequalities between rural and urban areas is the major problem of public health interventions to improve child health and survival in Sudan.

Keywords: Multiple indicator cluster survey; Cox model; risk factor; proportional-hazards model, joint effect.

1. INTRODUCTION

According to the United Nations Inter-Agency Group for Child Mortality Estimation (UN IGME) 2018 report, there has been observed progress in terms of child survival in the past few times in most regions of the world. When compared to the 1990s (where 1 in 11 children died before reaching age five), in 2017 there was a 1 in 26 mortality rates. Furthermore, the reduction of risk of death in the first month of life was accelerated in the period 2000–2017, compared with the 1990s, as the global reduction rate increased from 1.9 % in the 1990–2000 period to 4.0 % in the 2000–2017 period. Despite this reduction in the under-five mortality rate, there were an estimated 5.4 million newborn deaths in 2017, and half of those deaths occurred in sub-Saharan Africa (i.e. 76 deaths per 1 000 live births). Thus, sub-Saharan Africa has the highest under-five mortality rate and is among the regions showing the least progress. However, sub-Saharan Africa has seen a faster annual decline in its under-five mortality rate, with this annual rate of reduction doubling between 1990–2000 and 2000–2017 [1]. Further, as reported by United Nations: The Sustainable Development Goals, 2016, the priority of the Sustainable Development Goals and the target for the survival indicator of the new-born child was the decrease of the under-five child death percentage of 25 or fewer deaths per 1000 live births by 2030, specifically in countries like Sudan. Also, the report provided by United Nations: The Millennium Development Goals Report in 2015 indicates that the progress of reducing the under-five mortality rate was 51% from 91 deaths per 1000 live births in 1990 to 43 in 2015 over the past 25 years. However, there were many countries in Sub-Saharan Africa continue to give a high rate of under-five mortality estimated at 83 per 1000 live births in 2015 [2].

Under-five mortality refers to the risk of death among children before reaching age five. Sudan is one of the developing sub-Saharan African countries which has a high under-five mortality rate. This rate is defined as the probability per

1,000 that a newborn child will die before completing five years of age. Sudan, like other developing countries, suffers a high mortality rate among under-fives due to its civil war, the crisis in Darfur, and other socioeconomic factors such as the recent secession of South Sudan in 2011 [3]. According to UNICEF: Committing to Child Survival: A Promise Renewed Progress Report 2015, the countries affected by war, such as Sudan, have the risk of under-five mortality to be 80 times higher than those countries not affected by war. Also, Grusovin et al. (2015) estimated that, of the 20 countries with a high risk of newborns in the world, 9 were from war-torn countries including Sudan. When compared to other sub-Saharan countries, Sudan has remained in the headlines over the past decade primarily because of the under-five mortality rate, although there has been a steady minimal reduction of this rate among Sudanese children. Sudanese under-five mortality fell gradually from 177.10 deaths per live births in 1960 to 69.00 deaths per 1 000 live births in 2014 [3, 4].

In most African countries, several factors influence under-five mortality, including child spacing, maternal age and education level, traditional and cultural practices, vaccination coverage, and economic factors [5]. A study which was done in Sudan (Abdeldafie, 2018) showed that the factors that most influence under-five mortality are prematurity, pneumonia, measles, and neonatal pneumonia. However, these factors vary from state to state [6]. For instance, according to research which was conducted by Susuman in 2012 in Tanzania, under-five mortality was found to be affected by low maternal education and young maternal age, which indicates less experience with infant health in comparison with older mothers, shorter birth intervals, and higher parity [7]. A study conducted by Kapungwe in 2005 and other researchers has shown that there is a significant relationship between under-five mortality and unimproved sources of drinking water, duration of breastfeeding status, family size and age of the mother at the child's birth [5,8]. The authors further mentioned that the risk factors in Zambia were malaria, malnutrition, pneumonia, diarrhea,

a source of drinking water, and vaccination. As stated by Abu et al. (2015), in Nigeria the factors were malaria, complications of birth and delivery, and measles [9]. In Ethiopia, research done by Gebretsadik and Gebreyohannes (2016) and other studies revealed that the most significant factors affecting under-five mortality are related to the birth interval, family size, birth type, breastfeeding status, source of drinking water, mother's education, mother's income, area of residence, and father's education[10-12].

Since 1956 and 2003, Sudan suffers from a civil war in South Sudan and Darfur, respectively. Several studies revealed that under the presence of war, the risk of under-five mortality may increase due to violence, poverty, being a child soldier, and mental health impairment. Therefore, investigating under-five mortality in Sudan is a valid indicator to control Sudanese child deaths and survival and to identify factors associated with the children who died before reaching age 5.

This paper aims to investigate the prenatal effects on child mortality. Therefore, the main objective of the study is to monitor the situation of children and women in several states of Sudan. To achieve this objective, we use the survival analysis through the use of the Cox proportional-hazards model [13]. In this model, the prenatal checkups and related variables, including demographic variables, will be used as explanatory variables. Survival analysis, or time to an event, encompasses a wide variety of methods for analyzing the timing of events. The prototypical event is death, which accounts for the name given to these methods. Usually, this refers to the time variable as survival time, because it gives the time that a child has "survived" over a follow-up period. We also typically refer to the event as a failure, because the event of interest is usually death, disease incidence, or some other negative individual experience [14]. Further details of survival analysis, as well as the Cox model, will be discussed later.

2. METHODOLOGY

2.1 Survey Design

This study uses the 2014 Sudan Multiple Indicator Cluster Survey (MICS) conducted by the Central Bureau of Statistics in collaboration with several national institutions. For this study, technical assistance was given by the United Nations Children's Fund (UNICEF). In addition to

this, financial support was given by several international organizations, such as the World Health Organization (WHO), World Food Programme (WFP), United Nations Population Fund (UNFPA), and the Department for International Development (DFID) UK.

The Multiple Indicator Cluster Survey, which was developed by UNICEF in the 1990s, is an international household survey programme. In this survey, comparable data are collected internationally on a wide range of indicators to assess the situation of children and women worldwide. Generally, these kinds of survey aim to measure important indicators in countries to create accurate evidence for use in national policies (such as the Sudan Strategic Plan 2012–2016), as well as to control the process towards the Millennium Development Goals (MDGs) and other internationally agreed on commitments for the situation of children and women. This survey takes advantage of using MICS modules and its geographical coverage of the eighteen states in Sudan to have updated information for evaluating the situation of children and women in Sudan [15].

The survey was carried out in Sudan from August to December 2014 covering all the eighteen states of Sudan. It was designed to collect data based upon a variety of socioeconomic and health indicators but mainly focused on issues that directly affect the lives of children and women. The data were collected via completed interviews for 15,801 households drawn from a sample size of 18,000 households in all states of Sudan. The rate of response was 98 percent. 20,327 women were ranging between 15–49 years of age, and 14,751 children under five years of age. The data types can be considered as cross-sectional, individual, nationally representative, household, interview, and urban-rural representative. Key topics included in this survey are child and maternal health, education, immunization, family planning, and knowledge of HIV/AIDS. The survey also included information for tracking progress towards MDGs, specifically information related to health and mortality. Therefore, for this survey, 18,302 women aged 15–49 were interviewed from a sample of 16,801 households, and 14,081 questionnaires were completed for children under five years of age.

2.2 Study Variables

The response variable for this study is under-five child mortality in Sudan. The explanatory

variables used in this study are area, delivery type, education, marital status, mother's age at child's birth, place of delivery, received antenatal care, sex of the child, size of child at birth, state, twins, wealth index and weeks or months pregnant at first ANC unit. The socioeconomic and demographic factors used in this study were suggested by several researchers [5, 8, 9, 11, 16].

2.3 Statistical Methods

The basis for survival analysis is time to an event of interest, denoted as (T) , given the event occurred, or time to censoring, denoted as (C) . Time can be regarded as continuous or discrete and this main difference affects the analytic approach.

Moreover, Probability density functions, cumulative distribution functions, and the hazard function are the main concepts to the survival analysis analytic techniques. The statistical details are presented in the study as an introduction to survival analysis procedures or a general text on survival analysis [17].

The probability density function for the event time is denoted by $f(t)$, and is defined as the probability of the event at time t (for continuous-time), or by denoting the probability of failure in the interval $(m, m + 1)$ for discrete-time, π_m [14]. The corresponding cumulative density functions are defined as follows:

$$F(t) = \int_0^t f(t)dt \text{ for continuous } t; \text{ or}$$

$$F(m) = \sum_{k=0}^m \pi(k) \text{ for } t \text{ measured in discrete intervals of time}$$

The CDFs for survival time measure the probability that the event occurs at or before time t (continuous) or before the close of time period m (for discrete-time). Therefore, the survivor function $S(t)$, is the complement to the CDF and is defined as follows:

$$S(t) = 1 - p(T \leq t) = 1 - F(t) \text{ for continuous time; or}$$

$$S(m) = 1 - F(m)$$

The value of the survivor function for an individual is the probability that the event has not yet occurred at time t [13,18]. Furthermore, the idea of hazard function plays an important role in the interpretation of survival analysis models.

The hazard conditional probability is $h(t) = f(t)/s(t)h(t)$ or the conditional probability that the event will occur at time t given that it has not occurred before time t [19].

As the survey we consider is complex, we use PROC SURVEYPHREG for fitting a Cox proportional-hazards model [13]. This model is referred to as semi-parametric and assumes continuous time with proportional hazards among covariates. For the Cox model approach, the data set is again structured as a one record per person file with the age event variable. For the analysis, variance estimates, and hypothesis tests will be correctly estimated using the default Taylor series linearization method (TSL) of PROC SURVEYPHREG. The SURVEYPHREG procedure, by default, outputs the hazard ratio, which is the ratio of the probability that an event will occur at time t , given that it has not yet occurred [20-23].

This ratio is represented as follows:

$$\begin{aligned} HR_j &= \frac{h_0(t) \exp(\hat{\beta}_1 x_1 + \dots + \hat{\beta}_j(x_j + 1) + \dots + \hat{\beta}_p(x_p))}{h_0(t) \exp(\hat{\beta}_1 x_1 + \dots + \hat{\beta}_j(x_j) + \dots + \hat{\beta}_p(x_p))} \\ &= \exp(h_0(t) \exp(\hat{\beta}_j)) \end{aligned}$$

The formula demonstrates that the hazard ratio for a specified predictor denotes the multiplier that a one-unit change in that predictor will have on the expected hazard. For categorical predictors, the one-unit change in a predictor is compared to the omitted reference category. The following SAS code illustrates the use of PROC SURVEYPHREG with strata, cluster, and weight statements to identify the complex sample design variables and weight. The detail about the method can be found in different literature [13, 22-26].

3. RESULTS

The result of exploratory data analysis for under-five mortality is summarized in Table 1. The P-values presented in Table 1 are obtained from a chi-square test. The cross-tabulation analysis gives the state, place of residence, twins, sex of a child, marital status, mother's age at the birth, wealth index, and education, which are significantly associated with under-five mortality at the 5% level of significance. Table 1 indicates that there is a high prevalence of under-five mortality among children in rural and urban places of residence at 9.08% and 8.68%

respectively (P-value = 0.013). Moreover, Table 1 indicates that children living in the Blue Nile are more likely to die (13.97%, P-value < 0.000) when compared to other areas, followed by Central Darfur, East Darfur, Gadarif, South Kordofan and others. Children from average wealth status households are more exposed to under-five mortality (10.07%) and these households have a high percentage of children who die before age five, followed by poor (9.74%) and rich (6.93%) households (P-value < 0.000). Furthermore, from a total of 52 245 under-five children, 9.78 % of male children died before reaching age five (P-value < 0.001). From the total under-five children who participated in the survey, 26.68% of multiple births died before they reached age five (P-value < 0.000). The prevalence of under-five mortality is higher among mothers who were formerly married (12.72%, P-value < 0.000). Mothers whose age is less than 20 at birth are highly associated with under-five mortality (12.2%, P-value < 0.000). Children with illiterate mothers are more vulnerable to under-five mortality (10.49%), followed by primary (8.10%), secondary (6.13%), and higher education (4.16) with P-value < 0.000 (Table 1). Moreover, from a total of 1433 children who were delivered in the health institution, 8.93 % died before reaching age five. Similarly, from the total children who were delivered normally, 9.85 % have died before the age of five. Among mothers who have not received antenatal care while pregnant, 8.08 % of children died before the age of five. Furthermore, among the total under-five children included in the survey, 93.03 % who have medium weight survived up to age five, followed by large (92.03 %) and small (91.22 %). The majority of children were delivered at home. Among these children, 92.65 % were alive. 91.07 % of children who were delivered at health institutions have survived to reach age five. Among children who have been delivered normally, 90.15 % have reached age five.

For this study, PROC SURVEYPHREG was used to fit the Cox proportional-hazards model using complex sample data [13, 27]. This model is considered semi-parametric and assumes continuous time with proportional hazards among covariates. Model selection was attained by first including all covariates into the model and then evaluating whether interaction terms needed to be incorporated. All covariates and their interactions were fitted into the model at the same time and only those that were statistically significant were retained in the final model. The

final selected model for under-five child mortality contained thirteen main effects and six two-way interaction effects.

From the result, it can be observed that tests of the global null hypothesis (Likelihood Ratio = 489.92, P-value <.0001 and Wald = 176.45, P-value <.0001) indicates high significant values. Therefore, a null hypothesis, which states that all the model predictors are equal to zero is rejected.

Table 2 is the Analysis of Maximum Likelihood Estimates (MLE) table, including hazard ratio, confidence limits, and P-value. Before proceeding with a final interpretation of the Cox model results, a test of the proportional-hazards assumption for the model considered is suggested. The estimated survivor functions were plotted for selected significant main effect covariates. Fig. 1 shows the Estimated Survivor Functions by marital status, age at birth, place of residence, and place of delivery. From the figure, minimal or no evidence of lines crossing can be seen and thus the proportional-hazards assumption underlying the Cox model is not violated for these covariates.

After the verification of the proportional-hazards assumption, interpretation of the model result proceeds. Table 2 presents the significant covariates in the model. It indicates that place of residence, area, wealth index, twin child, the weight of a child, place of delivery, type of delivery, birth order, marital status, age of women, mother's age at the birth, age at first marriage/union and children ever born were found to significantly affect under-five mortality at 5 % level of significance. In addition to the main effects, the model contains six two-way interaction effects These are presented in Table 3.

As stated above, Table 2 presents odds ratio estimates associated with the main effects in the model. The results indicate that under-five mortality is higher for children whose weight was small (OR=1.272, P-value = 0.041; 95% CI: 1.097, 1.428) and large (OR=1.097, P-value = 0.048; 95% CI: 1.005, 1.217), when compared to the average weighted under-five children at birth. Based on the results, children born at health institutions are 85.5% less likely to be dead before reaching age five compared to those born in other places of delivery. Similarly, children born at home (OR=0.143, P-value < 0.000; 95% CI: 0.059, 0.346) are less likely to be dead before

Table 1. Distribution of under-five mortality and its associated selected factors

Factors		Still alive				Total	P-value
		Yes		No			
		Number	%	Number	%		
Area	Urban	13,492	91.32	1,283	8.68	14,775	0.013
	Rural	34,067	90.92	3,403	9.08	37,470	
State	Blue Nile	3,092	86.03	502	13.97	3,594	0.000
	Central Darfur	2,628	88.46	343	11.54	2,971	
	East Darfur	3,106	88.54	402	11.46	3,508	
	Gadarif	2,839	89.59	330	10.41	3,169	
	Gezira	2,856	93.24	207	6.76	3,063	
	Kassala	2,452	92.70	193	7.30	2,645	
	Khartoum	2,403	93.10	178	6.90	2,581	
	North Darfur	2,849	90.33	305	9.67	3,154	
	North Kordofan	2,465	93.05	184	6.95	2,649	
	Northern	2,201	93.70	148	6.30	2,349	
	Red Sea	1,596	94.05	101	5.95	1,697	
	River Nile	2,044	95.20	103	4.80	2,147	
	Sinnar	2,615	91.24	251	8.76	2,866	
	South Darfur	3,119	90.88	313	9.12	3,432	
	South Kordofan	3,446	89.72	395	10.28	3,841	
	West Darfur	2,760	90.20	300	9.80	3,060	
West Kordofan	2,485	92.83	192	7.17	2,677		
White Nile	2,603	91.59	239	8.41	2,842		
Wealth Index	Poor	22,697	90.26	2,449	9.74	25,146	0.000
	Middle	10,298	89.93	1,153	10.07	11,451	
	Rich	14,564	93.07	1,084	6.93	15,648	
Sex of child	Male	24,425	90.22	2,649	9.78	27,074	0.000
	Female	23,134	91.91	2,037	8.09	25,171	
Twins	Single	46,416	91.58	4,270	8.42	50,686	0.000
	Multiple	1,143	73.32	416	26.68	1,559	
Size of child at birth	Large	762	92.03	66	7.97	828	0.068
	Average	2,671	93.03	200	6.97	2,871	
	Small	1,745	91.22	168	8.78	1,913	
Place of Delivery	Home	3,868	92.65	307	7.35	4,175	0.154
	Health institution	1,305	91.07	128	8.93	1,433	
	Other	14	93.33	1	6.67	15	
Delivery type	Normal delivery	842	90.15	92	9.85	934	0.098
	Assisted delivery	462	92.77	36	7.23	498	
Marital status	Currently married	45,224	91.23	4,346	8.77	49,570	0.000
	Formerly married	2,334	87.28	340	12.72	2,674	
Mother's age at birth	<20 years	9,528	87.80	1,324	12.20	10,852	0.000
	20–34	33,574	91.86	2,975	8.14	36,549	
	35+	4,457	92.01	387	7.99	4,844	
Education	None	24,989	89.51	2,929	10.49	27,918	0.000
	Primary	14,122	91.90	1,244	8.10	15,366	
	Secondary	6,724	93.87	439	6.13	7,163	
	Higher	1,705	95.84	74	4.16	1,779	
Received antenatal care	Yes	4,227	92.31	352	7.69	4,579	0.668
	No	967	91.92	85	8.08	1,052	
Weeks or months pregnant at first ANC-unit	Weeks	238	90.84	24	9.16	262	0.653
	Months	3,964	92.40	326	7.60	4,290	
	Special values	25	92.59	2	7.41	27	

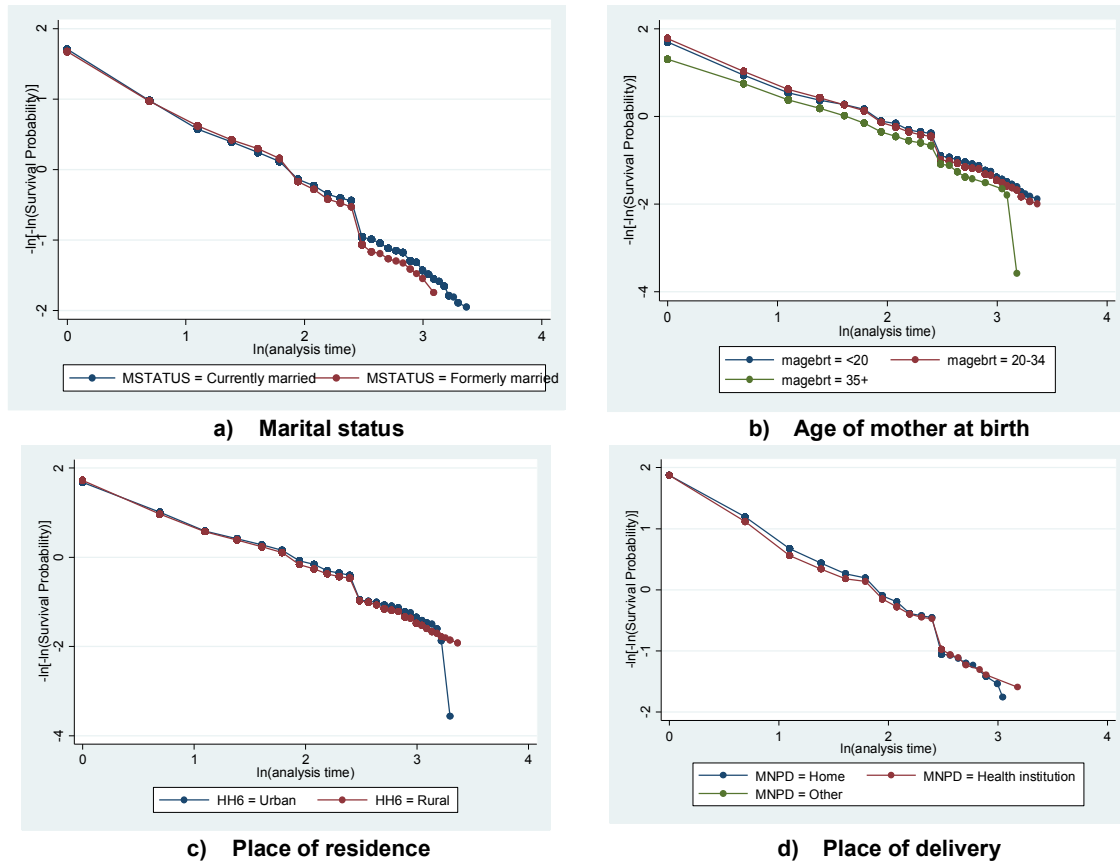


Fig. 1. Estimated survivor functions by marital status, age of mother at birth, place of residence and place of delivery

reaching age five compared with other types of delivery. Mothers who were married at the time of the survey were more likely to have higher under-five child mortality (OR=1.392, P-value =0.012; 95% CI: 1.077, 1.799) as compared to formerly married mothers. From Table 2, it is indicated that the mother’s age at birth is significantly associated with under-five mortality. Therefore, mothers whose age is more than 35 years (OR = 1.260, P-value < 0.000; 95% CI: 1.120, 1.420) have higher under-five mortality compared to mothers whose age at birth is less than 20 years. Furthermore, it was revealed that the current age of women is significantly related to under-five mortality. Therefore, for a unit change in the current age of a mother, the under-five child mortality is higher by 66.8 % (OR = 1.668, P-value = 0.020; 95% CI: 1.091, 2.551) by holding the other covariates constant. Furthermore, for a unit change for mother’s age at first marriage, the under-five child mortality is lower by 27.3% (OR = 0.727, P-value = 0.041;

95% CI: 0.537, 0.986) by holding the other factors constant. Similarly, children ever born (OR = 0.491, P-value = 0.039; 95% CI: 0.250, 0.964) was found to be significant compared against under-five mortality.

3.1 Interaction Effects

In addition to the main effects, there are interaction effects that influence the under-five mortality of Sudan. Of these effects, the first is the interaction between the sex of a child and the place of residence. The result is presented in Table 3.

As can be seen in Fig. 2, the relationship between sex of a child and place of residence indicates that the risk of under-five child mortality is higher for a male under-five child who lives in an urban area. However, for a female child, under-five mortality is higher in rural areas.

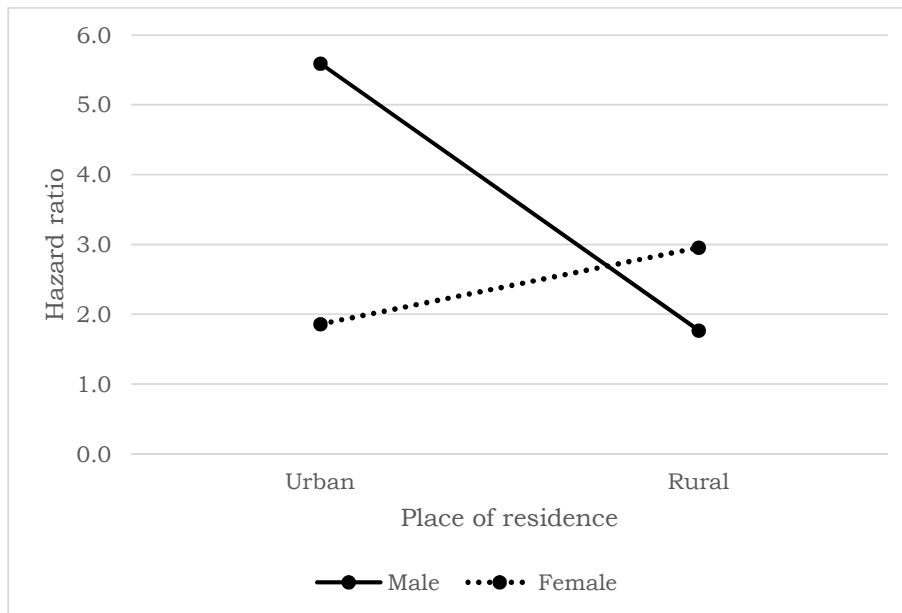


Fig. 2. Log odds associated with under-five child mortality by place of residence and sex of a child

Table 2. Parameter estimates of main effects for under-five mortality using a cox proportional-hazards model

Covariates	HR	95% HR CL		P-value
		Lower	Upper	
Intercept	0.149	0.136	0.163	0.000
Place of residence (Ref. Urban)				
Rural	1.620	1.374	1.970	0.018
State (Ref. River Nile)				
Blue Nile	1.094	0.965	1.240	0.160
Central Darfur	1.079	0.935	1.245	0.297
Gadarif	1.062	0.922	1.224	0.404
Gezira	1.109	0.935	1.314	0.234
Kassala	1.151	0.977	1.355	0.092
Khartoum	1.129	0.953	1.337	0.160
North Darfur	1.057	0.909	1.229	0.474
North Kordofan	0.986	0.849	1.144	0.850
Northern	1.078	0.893	1.301	0.434
Red Sea	0.942	0.790	1.124	0.508
River Nile	1.270	1.078	1.497	0.004
Sinnar	1.149	0.976	1.354	0.096
South Darfur	1.101	0.962	1.261	0.161
South Kordofan	1.089	0.949	1.250	0.224
West Darfur	1.169	1.010	1.354	0.037
West Kordofan	1.308	1.079	1.585	0.006
White Nile	1.059	0.883	1.269	0.537
Wealth index	7.004	1.318	11.217	0.024
Sex of child (Ref. Male)				
Female	1.188	0.535	2.640	0.663
Child is twin (Ref. Multiple)				
Single	0.720	0.650	0.800	0.000

Covariates	HR	95% HR CL		P-value
		Lower	Upper	
Weight of child (Ref. Small)				
Average	1.272	1.097	1.428	0.041
Large	1.097	1.005	1.217	0.048
Place of delivery (Ref. Other)				
Home	0.143	0.059	0.346	0.000
Health institution	0.145	0.060	0.350	0.000
Type of delivery (Ref. Normal delivery)				
Assisted delivery	0.150	0.027	0.819	0.030
Birth order	0.947	0.533	1.681	0.848
Marital status (Ref. Formerly married)				
Currently married	1.392	1.077	1.799	0.012
Age of women (years)	1.668	1.091	2.551	0.020
Mother's age at birth (Ref. < 20)				
20–34	1.030	0.980	1.080	0.192
35+	1.260	1.120	1.420	0.000
Educational level (Ref. Secondary)				
Higher	6.593	0.389	111.764	0.185
None	3.730	0.243	57.319	0.335
Primary	6.241	0.927	12.520	0.055
Age at first marriage/union	0.727	0.537	0.986	0.041
Children ever born	0.491	0.250	0.964	0.039

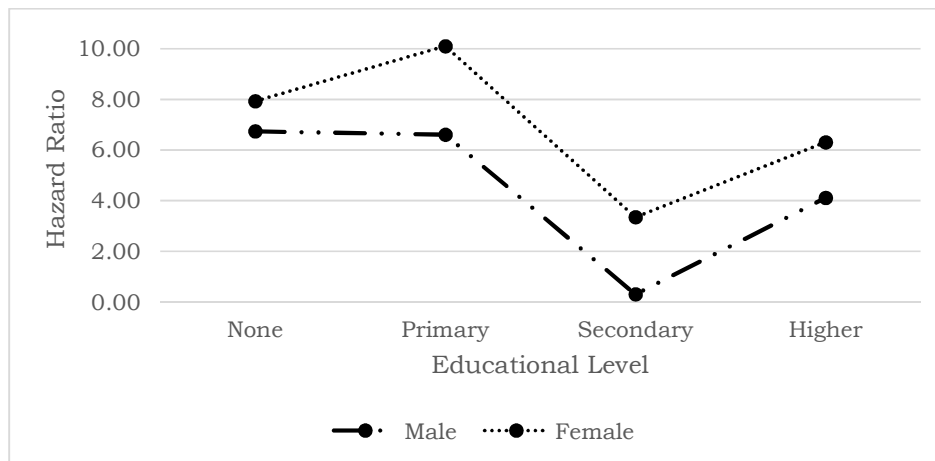


Fig. 3. Log odds associated with under-five child mortality by educational level and sex of a child

The other interaction effect is between the education level and sex of a child (Table 3). The result from Fig. 3 shows that both male and female under-five mortality is higher for mothers who have attended primary school and is followed by mothers who have no education. As can be seen from the figure, for female children, under-five mortality is higher with reference to all levels of education.

The interaction between the state and sex of a child was found to be significant. The result is presented in Fig. 4. The result indicates that the

risk for a male child to not reach the age of five is higher in Gezira state. In contrast, the risk of a child dying before age five is higher for females for all states except the Gezira state (Table 3).

The HR values for the interaction between birth type (child is a twin) and the sex of a child is given in Fig. 5. Based on the result, under-five child mortality was significantly higher for single birth than for multiple births (OR=0.432, P-value= 0.024). There was, however, higher under-five child mortality for female children for both single and multiple births (Table 3).

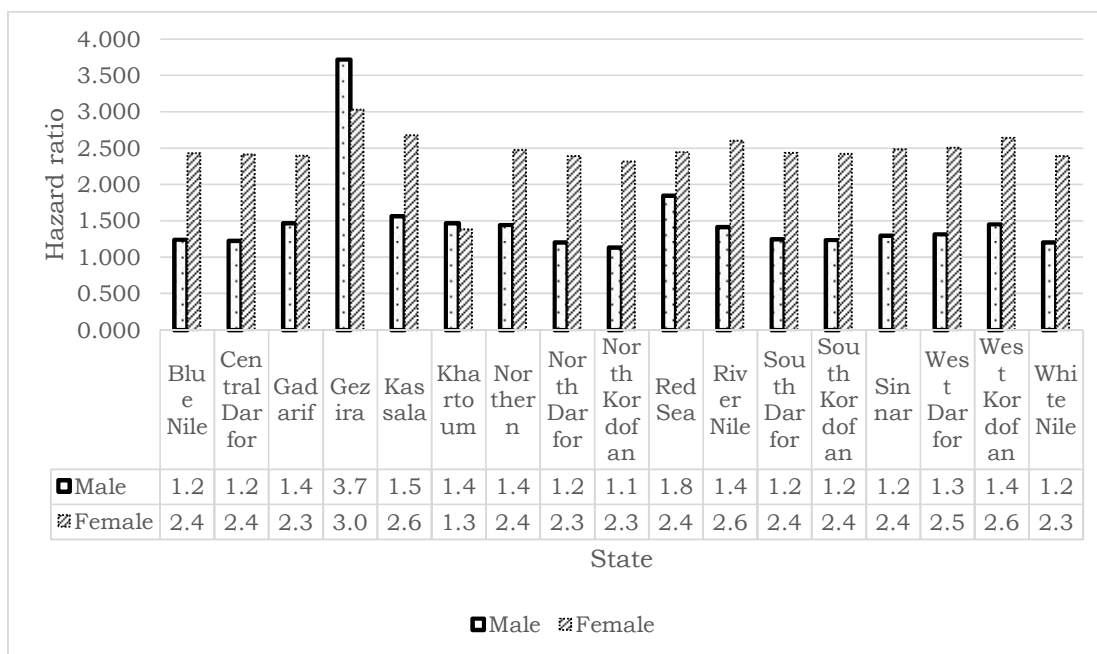


Fig. 4. Log odds associated with under-five child mortality by state and sex of a child

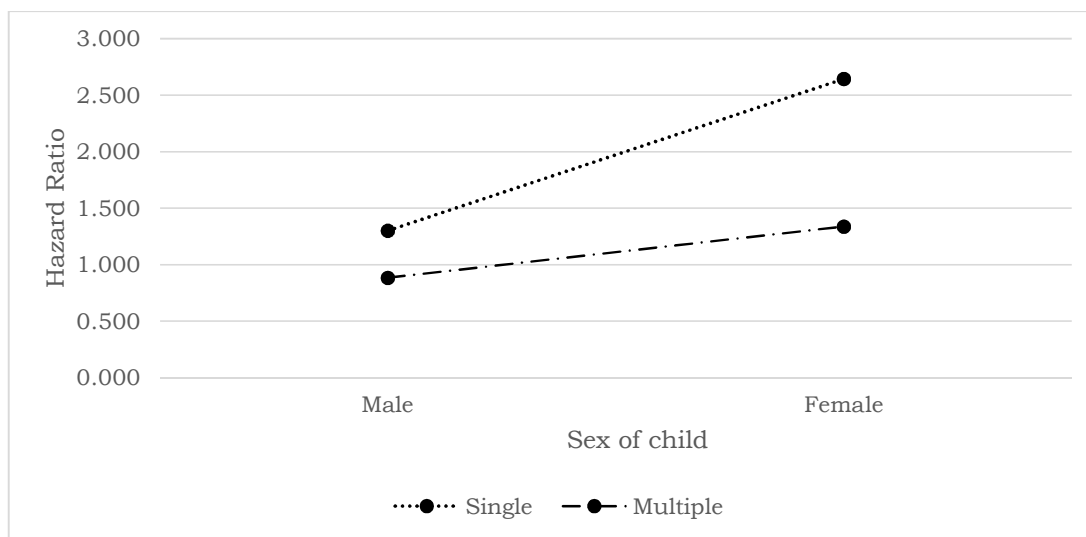


Fig. 5. Log odds associated with under-five child mortality by birth type and sex of a child

The relationship between the type of delivery and sex of a child is presented in Table 3 and Fig. 6. The figure shows all data points, with under-five child mortality plotted against the sex of child and type of delivery. As the result indicates, male children with both delivery types are less likely to die before reaching age five. Furthermore, mothers who gave birth with normal delivery have a higher chance of under-five child mortality compared to assisted delivery for both male and female children.

4. DISCUSSION

In this study, the Cox proportional-hazards model was employed to investigate all possible determinants of under-five child mortality and to capture the interconnectedness among various risk factors within the model. The study used the 2014 Multiple Indicator Cluster Survey in Sudan and SAS version 9.4 for the analysis of the data. Observing more carefully within groups of determinants, our analysis confirms the

importance of the place of residence, area, wealth index, twin child, the weight of a child, place of delivery, type of delivery, birth order, marital status, age of women, mother's age at

the birth, age at first marriage/union and children ever born as major statistically significant risk factors. In Sudan, the mortality rate is approximately 63 per 1 000 live births [28].

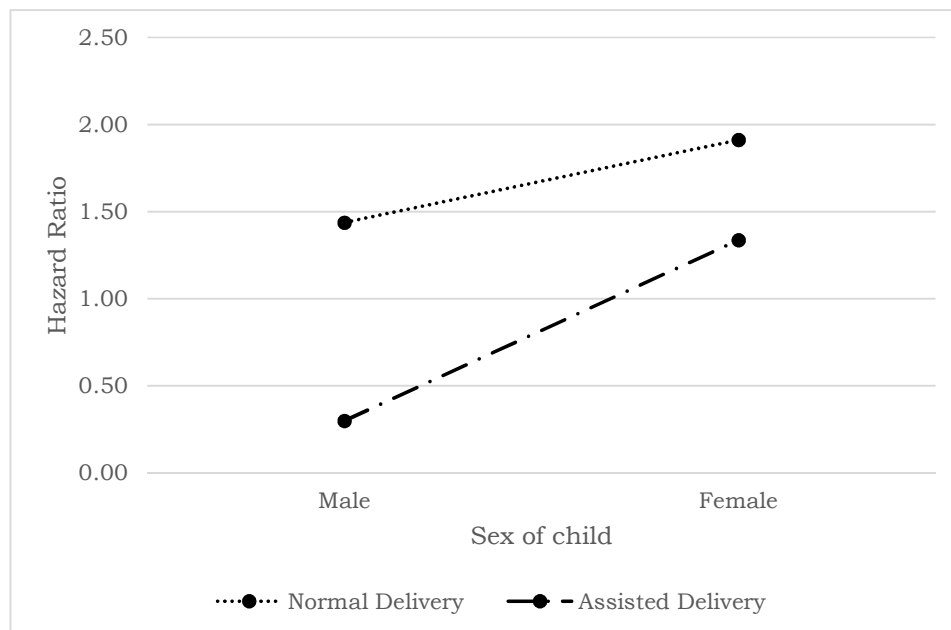


Fig. 6. Log odds associated with under-five child mortality by type of delivery and sex of a child

Table 3. Parameter estimates with two-way interaction effects for under-five child mortality

Covariates	HR	95% HR CL		P-value
		Lower	Upper	
Sex of child and place of residence (Ref. Rural and female)				
Urban and male	5.444	0.316	93.900	0.242
Urban and female	0.524	0.119	2.300	0.389
Rural and male	1.641	1.484	4.467	0.022
State and sex of child (Ref. White Nile and male)				
Northern and male	0.219	0.010	4.709	0.330
Northern and female	0.064	0.002	2.164	0.125
River Nile and male	0.000	0.000	0.001	0.000
River Nile and female	0.001	0.000	0.012	0.000
Red Sea and male	0.758	0.090	6.348	0.797
Red Sea and female	0.169	0.018	1.598	0.120
Kassala and male	0.268	0.037	1.922	0.189
Kassala and female	0.192	0.025	1.453	0.109
Gadarif and male	0.262	0.035	1.939	0.188
Gadarif and female	0.064	0.007	0.589	0.016
Khartoum and male	0.192	0.013	2.722	0.221
Khartoum and female	0.052	0.003	0.821	0.036
Gezira and male	2.462	0.140	43.244	0.536
Gezira and female	0.586	0.039	8.821	0.698
Child is twin and sex of child (Ref. Multiple and male)				
Single and male	0.432	0.208	0.894	0.024
Single and female	0.587	0.258	1.335	0.202

Covariates	HR	95% HR CL		P-value
		Lower	Upper	
Type of delivery and sex of child (Ref. Assisted delivery and male)				
Normal delivery and male	1.288	0.829	2.002	0.258
Normal delivery and female	0.575	0.345	0.958	0.034
Educational level and sex of child (Ref. Higher and male)				
None and male	0.236	0.083	0.672	0.007
None and female	1.240	0.494	3.110	0.645
Primary and male	0.219	0.085	0.563	0.002
Primary and female	2.520	1.206	5.267	0.014
Secondary and male	0.161	0.063	0.414	0.000
Secondary and female	2.016	0.903	4.500	0.087
Place of residence and wealth index (Ref. Rural)				
Urban	1.524	1.033	2.249	0.034

The results show that the weight of a child at birth is positively associated with under-five child mortality. Under-five children who have small and large weights at birth are at a higher risk of dying before reaching five years. Similar to other studies carried out [16], this and similar studies confirmed that small weighted children were associated with a higher risk of child mortality [29, 30]. Similarly, based on demographic factors associated with under-five mortality, our analysis showed that mothers who were married at the time of the survey most likely have higher under-five child mortality as compared to formerly married mothers. In addition to this, the mother's age at birth is significantly associated with under-five mortality. Furthermore, the findings indicate that mothers whose age is more than 35 years have high under-five child mortality rates compared to mothers whose age at birth is less than 20 years. Recent studies conducted in Eastern Africa reveals that sex of the child, birth interval, type of birth, region of residence, and mother's education were found to be associated with under-five mortality. This result supports our study [11, 31, 32]. Moreover, for a unit change in the current age of a mother, the under-five child mortality is higher. However, for a unit change for a mother's age at first marriage, the under-five child mortality is lower and the chance of a child reaching age five is low for an increased mother's age at first marriage. Similarly, children ever born was found to be significant against under-five mortality. This finding is supported by previous studies. As the literature indicates child health can be influenced by many factors including the educational level of parents, access to health services, and related factors [33, 34]. In this study, two-way interaction effects were found to be statistically significant with under-five child mortality. Therefore, a study conducted by Mosley and Chen (1984) showed that child mortality is influenced by a joint effect of

socioeconomic, biological, environmental, and behavioral factors. Similar studies conducted in different countries reported that under-five mortality is influenced by socioeconomic status [34-37]. Therefore, birth weight, mother's current age, place of residence, mother's education, place of delivery, birth order, sex of a child, the religion of parents, household headship, and household socioeconomic status are found to be influential factors concerning under-five mortality based on previous studies. Our findings support these facts [11, 35, 38].

5. CONCLUSION

Based on the Cox proportional-hazards model, this paper identified the determinants of under-five child mortality in Sudan. In general, the risk of under-five child mortality is higher for male under-five children who live in urban areas, but, for female children, it is higher in rural areas. Concerning the education level and sex of a child, under-five mortality is higher for both male and female children for mothers who have attended primary school and followed by mothers who have no education. About the state and sex of a child, the risk for a child not reaching the age of five is higher for Gezira state for males. In contrast, the risk of a child dying before age five is higher for females for all states except Gezira state. The other important joint factor found in this study is between birth type (child is a twin) and sex of the child. The result reveals that under-five child mortality is significantly higher for single births than for multiple births. Similarly, there is higher under-five child mortality for female children for both single and multiple births. On the other hand, male children with both delivery types are less likely to die before reaching age five. Furthermore, mothers who gave birth with normal delivery have a higher

chance of under-five child mortality compared to assisted delivery for both male and female children. In general, the wealth status of the household was found to be the major reason for under-five mortality in Sudan.

6. RECOMMENDATION

Based on the result, the lack of important policies targeted to reduce socioeconomic inequalities between rural and urban areas has a significant impact on public health interventions towards improving child health and survival in Sudan. Even though the government of Sudan takes measures to reduce the problem of under-five mortality, the problem is still high after applying many strategies and interferences by the federal government. Therefore, improving socioeconomic inequalities is important to improve child health and survival.

CONSENT

As per international standard or university standard guideline participant consent has been collected and preserved by the authors.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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