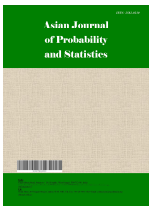

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The Effect of Exclusive Breastfeeding on Child Survival Using Modified Kaplan Meier Model (MKMM)

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Authors' contributions

This work was carried out in collaboration among all authors. Author MLD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author Kazeem Eyitayo Lasisi managed the analysis of the study. Author Kaneng Eileen Longji managed the literature searches. All authors read and approved the final manuscript.

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Abstract

Background: In Survival analysis, Kaplan-Meier estimator serves as a tool for measuring the frequency or the number of patients surviving medical treatment. Kaplan Meier estimates of survival data have become a better way of analyzing data in cohort study. Kaplan- Meier (K-M) is a non-parametric estimates of survival function that is commonly used to describe survivorship of a study population and to compare two study populations.
Aims: This research study is aimed at reducing the morbidity and mortality rate of children less than 6 months.
Methodology: 58,609 children less than six months were Exclusive Breastfed from the database. The analysis is done using both K-M and the modified K-M model to examine the effects of Exclusive Breastfeeding. The AIC and BIC was also used as the information criteria.
Results: Our results revealed that the K-M model 0.998566822 as the estimated survival probability of children under the ages of six months. Also showing, Exclusively Breastfed children stand the chance of 99% survival.
The modified K-M model also revealed 6.98276443909739 as the estimated survival probability, due to initiation of milk substitute and food supplement into the breastfeeding pattern. Showing about 70%

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chances of survival. Implying about 30% of the existence in one disease or the other or the risk of dying before the age of 5 years.
From the information criteria, the AIC (2.3119452169420) and BIC (7.8478797677756) in the Modified K-M are both lower compared to Existing Kaplan Meier (4.0012457354876) and (9.5371847322969) respectively. Modified K-M stand as the best model in knowing the types/amount of food to be added to breastfeeding pattern.
Conclusion: So far, the Modified Kaplan Meier Model has been verified and the findings agree that the life expectation will be improved by 99% if children are fed exclusively with breast milk while the life span is been reduced that can lead to death by 30% if the children have a mix feeding which agrees with why Exclusive Breastfeeding should be done.

Keywords: Survival analysis; Kaplan Meier; exclusive breastfeeding; Akaike information criterion; Bayesian information criterion.

Definitions

Breast: *Breast of an adult, consists of mammary gland and between15-20 lobes, where by the lobes gives the breast size and shape [17].*

Breast Feeding: *This is the process of breastfeeding a baby at least up to two years old regardless of addition of other complimentary foods.*

Breast Milk: *Milk is produced in the alveolus gland cells. Whereby these alveolus is made up of gland cells around a central duct. Breast milk is prepared and stored in female breasts (or mammary glands) for her infant offspring. Surrounding the gland cells are the myoepithelial cells which contract to cause milk ejection into the milk duct. Then it travels down the lactiferous ducts. It is a nutritive food for infants and children soon after birth up to two years old. The milk produces, consists of all required nutrients for child growth and development [18].*

Exclusive Breast Feeding (EBF): *Exclusive breastfeeding" is defined as no other food or drink, not even water, except breast milk (including milk expressed or from a wet nurse) for 6 months of life, but allows the infant to receive ORS, drops and syrups (vitamins, minerals and medicines) [20].*

Predominantly breastfed infants: *These infants may have been fed water-based liquids (e.g. plain water, juice and juice drinks, sugar water, etc.) in addition to breast milk. These infants would not have received milk based-liquids or food.*

1 Introduction

Appropriate analysis of survival data requires specific statistical methods that can deal with censored data. As the assessed outcome is frequently mortality, these techniques are subsumed under the term survival analysis. More generally, however, these techniques can be used for the analysis of the time until any event of interest occurs (e.g, recurrence of a disease; initial, breakthrough postoperative pain; or failure of an implanted medical device), and such data can thus also be called time-to-event or failure time data [1]. In medicine, time duration, from the patient had been diagnosed up to the time of his/her death. Survival analysis can answer questions such as: What proportion of patients will survive past a certain period of time? Of those who have not yet experienced an event, what is the rate of failure or event occurrence? Which treatment is more effective in prolonging life or reducing the duration of symptoms of disease? This article will describe the key components of a survival analysis and will review the interpretation of survival analysis, including Kaplan-Meier (KM) estimated [2].

Survival Analysis is a widely used in inferential statistical operation of clinical studies; especially in prospective studies. Though, its application is also found in epidemiology when testing for associations in epidemiology studies [3].

The usage of survival analytical methods is more pronounced in handling measurements derived from prospective studies by evaluating event occurrence, time of such event and the nature of the event. However, its usage can also be found in some retrospective studies in which this research work is a good example [4].

According to [5], he considered it as a timeline analysis that understudies some group of individuals with some prior experience with a view to looking forward to the occurrence of an event of interest.

The survival analysis is done to majorly help describe the pattern of survival over a time period; evaluate risk factors or treatment effect that affects survival duration; make comparison between different survival patterns of risk factors or treatments under investigations and as well make some estimated predictions of survival for a group of subjects or individuals with unique attributes [6]. There are five different types of censoring, namely: right, left, interval, doubly and middle censoring [7,8,9].

Kaplan- Meier (K-M) is a non-parametric estimates of survival function that is commonly used to describe survivorship of a study population and to compare two study populations. KM estimate is one of the best statistical methods used to measure the survival probability of patients living for a certain period of time after treatment.

Milk is the primary source of nutrition for new born at early stage of life before being able to digest other foods other than the milk, [10]. Breast milk is a liquid product from the mammary gland (Breast) of the human female naturally meant for her infant upbringing, having all the nutrients for normal growth and development of the baby from time of birth to the first 6 months of life.

Breastfeeding being the most natural and special gift from is an eminent public health tool for primary prevention of child morbidity and mortality. Research has also shown that breastfeeding is not simply a meal at the breast but also has significant and far-reaching effects on cognition, behavior, and mental health in children and mothers [11]. Infant feeding practices have a major role in determining the nutritional status of the child. Breastfeeding is a personal decision a mother needs to make carefully, taking into account the full benefits and burdens it will bring to both mother and baby.

Exclusive Breast Feeding (EBF) means that the infant receives only breast milk in the first 6 months of life. No other liquids or solids are given – not even water; with the exception of Oral Rehydration Solution, or Drops/Syrups of vitamins, mineral or Medicines [12]. This is the most effective form of infant feeding for the first six months of life [13].

Child survival is threatened by nutritional deficiencies, failure in practicing Exclusive Breast Feeding (EBF) are illnesses; particularly Malaria, Diarrheal diseases, Acute Respiratory Infections (ARI), and Vaccine Preventable Diseases (VPD), which account for the majority of morbidity and mortality in childhood [14,15].

Nutritional deficiencies are a major problem among developing countries. They can occur in all age groups, but the impact is more severe among children less than 6 months of age as this period is critical for child development, and irreversible damages can occur due to nutritional deficiencies.

Despite the many advantages of Exclusive Breast Feeding, the benefits of breast milk have been widely relatively unknown to mothers. In developing countries of the world, water and other liquids are added to the baby's diet in the first months of life rising infection from harmful bacteria and other pathogens.

This research study proposed a modified Kaplan Meier model which is aimed at reducing the morbidity and mortality rate of children less than 6 months.

The study examine the survival analysis of children less than 6 (six) months using modified Kaplan Meier and to this ends, it will assist Breastfeeding mothers, Ministry of Health, Stakeholders, physicians as well as researchers in planning feasible intervention and strengthening the existing factors on nutrition, and all other effects that relates to Exclusive Breast Feeding and child survival so as to support nutrition and reduce the morbidity and mortality rate.

This research focused on children nutrition, children less than 6 months and are being breastfed (exclusively and non-exclusive) with milk substitute, food substitute (water, grain, etc.) And breastfeeding mothers from the ages of 18 years and above. Women breastfeeding children above the ages of six months, mothers with serious health challenges, and children under intensive hospital/medical observations are exempted from the study.

2 Materials and Methods

$$\mathbf{S}_t = \frac{\text{Number of subjects living at the start – Number of subjects that died}}{\text{Number of subjects living at the start}} \quad (1)$$

$$\hat{S} = \prod_{i:t_i \le t} .(1 - \frac{d_j}{n_j}) \quad (2)$$

t_i: A time when at least one event happened.
d_j: Number of deaths that happened at time t_i
n_j: Individual known to survive (censored) at time t or number of subjects at-risk at i^{th}ordered time
h_i: Discreet hazard rate (probability of an individual with an event time t_i)

$$\mathbf{S}\ (t) = \prod\ (1 - \ h_i) \quad (3)$$

$$\mathrm{L}\ [h_{j:j\le i} / d_{j:j\le i,} n_{j:j\le i}] = \prod_{j=1}^{i} h^{d_j} . (1 - \ h_j)^{n_j - d_j} \quad (4)$$

Therefore the log likelihood will be;

$$\log(L) = \ \sum_{j=1}^{i} (d_j \log(h_i) + (n_j - \ d_j) \log(1 - \ h_i)) \quad (5)$$

Finding the maximum of log likelihood with respect to $\boldsymbol{h_i}$ yield;

$$\frac{\delta \log(L)}{\delta\ h_i} = \frac{d_i}{\hat{h}_i} - \frac{n_i - d_i}{1 - \hat{h}_i} = 0 \rightarrow \hat{h}_i = \frac{d_i}{n_i} \quad (6)$$

$$\hat{S} = \prod_{i:t_i \le t} (1 - \ \hat{h}_i) = \prod_{i:t_i \le t} (1 - \ \frac{d_i}{n_i}) \quad (7)$$

2.1 Survival model (Kaplan Meier)

$$\hat{S}\ (t) = \prod (1 - \ \frac{d_i}{n_i}) = (1 - \frac{d_1}{n_1}) \text{ x } (1 - \frac{d_2}{n_2}) \text{ x...x } (1 - \frac{d_i}{n_i}) \quad (8)$$

t_i:i^{th} ordered follow-up time
d_i: Number of deaths at i^{th} ordered time
n_i: Number of subjects at-risk at i^{th} ordered time

2.2 Modified model

$$\hat{S}\ (t) = \prod \left(1 - \ \frac{d_j}{n_j}\right) \theta_i \quad (9)$$

$$\text{Where } \theta = \alpha_{t_i} * \beta_{t_i} = (1 - \frac{d_1}{n_1})\,\theta_1 \text{ x } (1 - \frac{d_2}{n_2})\,\theta_2 \text{ x} \ldots \text{x } (1 - \frac{d_j}{n_j})\theta_n \quad (10)$$

t_i:i^{th} ordered follow-up time
d_i: Number of deaths at i^{th} ordered time
n_i: Number of subjects at-risk at i^{th} ordered time
α_{t_i}= Initiation of milk substitute (evaporated milk) at time *t*
β_{t_i}=Initiation of natural food/complementary (water, cooked grains, etc.) at time *t*

Kaplan-Meier estimator which serves as a tool for measuring the frequency or the number of patients surviving medical treatment. It is a non-parametric estimates of survival function that is commonly used to describe survivorship of a study population and to compare two study populations/cohort studies. It has been proven to be one of the best statistical methods used to measure the survival probability of patients living for a certain period of time after treatment [16].

The Modified KM stands out among other tools because no other tools shows the addition of other foods added to the model thereby giving the survival prediction rate to be 30% of children likely not to survive past the age of 5 years.

2.3 Testing model selection and consistency

$$\text{AIC} = -2log\ l(\hat{\Theta}) + 2p \quad (11)$$

$$\text{BIC} = -2\log l(\hat{\Theta}) + plogn \quad (12)$$

Where:

L ($\hat{\Theta}$) = Corresponding Likelihood
Θ = Maximum Likelihood Estimates
p = Number of Parameters
n = Sample size

Where the model with the lowest AIC being the best model among all models specified for the data at hand. If only poor models are considered, the AIC will select the best of the poor models. While the BIC procedure tests the consistency [17,18].

Table 1. Kaplan Meier table of survival analysis

Serial number	Year (Time (t))	Event (d)	Risk Set (n)	Censored (c)	Factor (1 - $\frac{d}{n}$)	$\hat{S}(t)$
1.	0	0	58,609	0	0	1
2.	1986	2	58609	1	0.999965876	0.999965876
3.	1987	2	58607	1	0.999965874	0.999931751
4.	1988	2	58605	1	0.999965873	0.999897626
5.	1989	0	58605	0	1	0.999897626
6.	1990	0	58605	0	1	0.999897626
7.	1991	0	58605	0	1	0.999897626
8.	1992	0	58605	0	1	0.999897626
9.	1993	0	58605	0	1	0.999897626
10.	1994	1	58605	1	0.999982936	0.999880564
11.	1995	1	58604	1	0.999982936	0.999863502
12.	1996	1	58603	1	0.999982936	0.99984644
13.	1997	0	58602	0	1	0.99984644
14.	1998	5	58602	1	0.999914679	0.999761132
15.	1999	1	58597	1	0.999982934	0.99974407

Serial number	Year (Time (t))	Event (d)	Risk Set (n)	Censored (c)	Factor (1 - $\frac{d}{n}$)	$\hat{S}(t)$
16.	2000	8	58596	1	0.999863473	0.999607578
17.	2001	2	58588	1	0.999965863	0.999573455
18.	2002	0	58586	0	1	0.999573455
19.	2003	3	58586	1	0.999948793	0.99952227
20.	2004	4	58583	1	0.999931721	0.999454023
21.	2005	5	58579	1	0.999914646	0.999368716
22.	2006	9	58574	1	0.99984635	0.999215163
23.	2007	2	58565	1	0.99996585	0.99918104
24.	2008	3	58563	1	0.999948773	0.999129854
25.	2009	1	58560	1	0.999982923	0.999112792
26.	2010	7	58559	1	0.999880463	0.998993361
27.	2011	5	58552	1	0.999914606	0.998908053
28.	2012	3	58547	1	0.999948759	0.998856868
29.	2013	5	58544	1	0.999914595	0.998771561
30.	2014	4	58539	1	0.99993167	0.998703315
31.	2015	3	58535	1	0.999948749	0.99865213
32.	2016	5	58532	1	0.999914577	**0.998566822**
	0	0	58527			

3 Results

$$\hat{S}(t) = \prod \left(\mathbf{1} - \frac{\boldsymbol{d_1}}{\boldsymbol{n_1}}\right) \text{ x } \left(\mathbf{1} - \frac{\boldsymbol{d_2}}{\boldsymbol{n_2}}\right) \text{ x } \left(\mathbf{1} - \frac{\boldsymbol{d_3}}{\boldsymbol{n_3}}\right) \text{ x...x } \left(\mathbf{1} - \frac{\boldsymbol{d_i}}{\boldsymbol{n_i}}\right) = \mathbf{0.998566822}$$

The result **0.998566822** above shows the survival of children under the ages of six (6) months in West African countries.

AIC $= -2 \log L(\hat{\Theta}) + 2p$
= -2 x *log* (0.998566822) + 2(2)
= -2 x -0.000622867743 + 4
= 0.0012457354876 + 4
= **4. 0012457354876.**

BIC $= -2 \log L(\hat{\Theta}) + plogn$
= -2 x *log* (0.998566822) + 2 x log (58609.7)
= -2 x -0.000622867743 +2 x 4.7679694984046
= 0.0012457354876 + 9.5359389968093
= **9.5371847322969**

$$\hat{S}(t) = \prod \left(1 - \frac{d_j}{n_j}\right) \theta_i \qquad \text{Where } \theta = \alpha_{t_i} * \beta_{t_i}$$

$$\hat{S}(t) = \prod \left(\mathbf{1} - \frac{\boldsymbol{d_1}}{\boldsymbol{n_1}}\right) \theta_1 \text{ x } \left(\mathbf{1} - \frac{\boldsymbol{d_2}}{\boldsymbol{n_2}}\right) \theta_2 \text{ x...x } \left(\mathbf{1} - \frac{\boldsymbol{d_i}}{\boldsymbol{n_i}}\right) \theta_n = \mathbf{6.98276443909739}$$

From the result above **6.98276443909739**, as soon as milk supplement, natural food supplement (water, cooked grains, etc.) was initiated, the figure grown and reduces the quality of life in children under ages of six (6) and they stand the risk of dying before age 5 years.

AIC $= -2 \log L(\hat{\Theta}) + 2p$
= -2 x *log* (6.98276443909739) + 2(2)
= -2 x 0.8440273915289 + 4
= -1.688054783057 + 4
= **2.3119452169420**

BIC = $-2\log L(\hat{\theta}) + plogn$
= -2 x *log* (6.98276443909739) + 2 x log (58609.4)
= -2 x 0.8440273915289 + 2 x 4.7679672754163
= -1.688054783057 + 9.5359345508326
= **7.8478797677756**

Table 2. The survival function for data collected on complementary feeding and milk substitute

Years	Total	Milk Sub.	Compl. Food	α	B	Ɵ	d	n	1 - d/n	(1 - d/n)Ɵ	$\hat{S}(t)$
	0	0	0	0	0	0	0	58604			1
2000	3830	4	28	153.2	1072.4	164291.68	8	58604	0.999863	164304	164304
2005	1363	3	10	40.89	136.3	5573.307	5	58596	0.999915	5577	916323408
2006	7479	24	71	1794.96	5310.09	9531399.154	9	58591	0.999846	9530189	8.73274E+15
2007	2635	4	12	105.4	316.2	33327.48	2	585821	0.999966	33326	2.91E+20
2008	3784	3	16	113.52	605.44	68729.55	3	58580	0.999949	68744	2.00E+25
2009	2966	2	13	59.52	385.58	22872.61	1	58577	0.999983	22885	4.58E+29
2010	7784	33	69	2568. 72	5370.96	13796492.37	7	58576	0.99988	13798033	6.32E+36
2011	6396	19	67	1215.24	4285.32	5207303.4	5	58569	0.999915	5207573	3.29E+43
2012	2842	4	32	113.68	909.44	103385.14	3	58564	0.999949	103416	3.40E+48
2013	6209	14	56	869.26	3477.04	3022451.79	5	58561	0.999915	3116659	1.06E+55
2014	3901	6	48	234.06	1872.48	438272.67	4	58556	0.999932	438265	4.65E+60
2015	3230	3	41	96.91	1324.3	128324.67	3	58552	0.999949	128366	5.97E+65
2016	6185	6	51	371.1	3154.35	1170579.29	5	58549	0.999915	1170555	**6.98E+71**
	58604										

4 Discussion

Child malnutrition has become a global embarrassment, particularly in the developing countries, where malnutrition is the attributable cause of more than half of all child deaths. In West and Central Africa – the regions with some of the highest child malnutrition, morbidity and mortality rates worldwide – 56 percent child deaths could be averted if children were not malnourished [19].

From our analysis, the Kaplan Meier model 0.998566822 from Table 1 shows the estimated survival probability of children under the ages of six months. This result also shows that exclusively breastfed children stand the chance of 99% survival. This implies that children who are exclusively breastfed are almost certain to survive above past the age of 5 years, and also live a healthy life free of diseases. While the result of the modified Kaplan Meier model reveals 6.98276443909739 from Table 2 which shows the estimated survival probability, due to initiation of milk substitute and food supplement into the breastfeeding pattern. This shows that children below 6 months introduced to milk substitutes, food supplements have about 70% chances of survival. This implies that children who are introduced to milk supplements and complementary foods stand the chance of about 30% of the existence in one disease or the other or the risk of dying before the age of 5 years.

The AIC for the Existing Kaplan Meier model (4.0012457354876) and BIC (9.5371847322969). Against the modified Kaplan Meier model, (2.3119452169420) and (7.8478797677756) respectively.

The AIC and BIC in the Modified Kaplan Meier are both lower than that of the Existing Kaplan Meier thereby, making the Modified Kaplan Meier model the best model and more consistent than the existing Kaplan Meier in knowing the types/amount of food to be added to breastfeeding pattern.

The first objective investigates the adequacy of the fitted model for the data. The result reveals that the Modified Kaplan Meier model, having proposed some components to the existing Kaplan Meier (α, β) and is found out to be adequate.

The second objective compared the modified survival model against the existing model to see if the modified model agrees with the theory of World Health Organization (WHO) about the standard of Exclusive Breastfeeding. The finding confirms the purpose/aim of doing Exclusive Breastfeeding, the research investigates children who are fed with Breast milk and cereals/milk substitute and found that it reduces their life expectation by 30% against the children who are Exclusively Breastfed 99% which agrees with the World Health Organization's standard that Infants should be exclusively breastfed for the first six months of life to achieve optimal growth, development and health. Thereafter, infants should receive nutritionally adequate and safe complementary foods, while continuing to breastfeed for up to two years or more [12].

4.1 Information criteria

4.1.1 Kaplan Meier (Survival Model)

AIC = 4. 0012457354876.
BIC = 9.5371847322969

4.1.2 Modified Kaplan Meier

AIC = 2.3119452169420
BIC = 7.8478797677756

From the model selection and consistency, the Modified Kaplan Meier is the best model over the existing Kaplan Meier survival model. From figures above, the AIC and BIC in the Modified Kaplan Meier are lower than that of the Existing Kaplan Meier thereby making the Modified models more acceptable and consistent.

5 Conclusion

This study introduced a Modified Kaplan Meier model. It proposed some components to the existing Kaplan Meier (α, β) and found out to be adequate. The model parameter **α** represents milk substitutes while **β** represents food supplement other than the natural breast milk.

The population sample of 58,609 was extracted from UNICEF Global database on Infant and Young Child Feeding.

The result for the existing Kaplan Meier model 0.998566822 shows the estimated survival probability of children under the ages of six months. The result indicates that exclusively breastfed children stand the chance of 99% of survival and also live a healthy life free of diseases.

While the result of the modified Kaplan Meier model 6.98276443909739 shows the estimated survival probability, due to initiation of milk substitute and complementary food into the breastfeeding pattern. This indicates that children below 6 months introduced to milk supplement and food supplement have about 70% chances of survival and stand the chance of about 30% of the existence in one disease or the other and also stand the risk of dying before the age of 5.

Comparing the information criteria, that is AIC and the BIC of the existing Kaplan Meier and the Modified Kaplan Meier, the AIC and the BIC of the existing Kaplan Meier returns the values 4. 0012457354876 and 9.5371847322969 respectively, while the AIC and the BIC of the modified model returns the value of 2.3119452169420 and 7.8478797677756 respectively.

The first objective was to investigate the adequacy of the fitted model for the data. The result reveals that the Modified Kaplan Meier model, having proposed some components to the existing Kaplan Meier (α, β) and is found out to be adequate.

The second objective was to compare the modified survival model against the existing model to see if the modified model agrees with the theory of World Health Organization (WHO) about the standard of Exclusive Breastfeeding.

The finding confirms the purpose/aim of doing Exclusive Breastfeeding, the research investigates children who are fed Breast milk and cereals/milk substitute and found that it reduces their life expectation by 30% against the children who are Exclusively Breastfed 99% which agrees with the World Health Organization's standard.

The application of Modified Kaplan Meier has been verified and the findings agrees that the life expectation will be improved by 99% if children are fed exclusively while the life span is been reduced that can lead to death by about 30% if the children have a mix feeding (Natural Breast milk with Cereals/milk substitute) which agrees with why Exclusive Breastfeeding should be done.

Competing Interests

Authors have declared that no competing interests exist.

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