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Propensity Score Adjusted Survival Analysis: Estimating the True Effect of Birth Spacing on Neonatal and Infant Mortality in Bangladesh

Rubaiya Ahmed[1], Sabina Sharmin[1*] and Mohammad Eftakhar Uddin[2]

[1]Department of Statistics, University of Dhaka, Dhaka, Bangladesh
[2]Department of Statistics, Tejgaon College, Dhaka, Bangladesh
[*]Correspondence should be addressed to Sabina Sharmin
(Email: sabina.sharmin@du.ac.bd)

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Abstract

The study of neonatal and infant mortality rates reflect the socioeconomic progress and quality of life of a country. They are also useful in identifying subdivision of the child population that are at greater risk of dying. This study introduced propensity score adjusted survival analysis, namely propensity score adjusted Kaplan-Meier estimator and weighted log-rank test, propensity score adjusted and weighted Cox proportional hazard regression model, to determine the true effect of birth spacing on early neonatal, neonatal, and infant mortality in Bangladesh. It was found that, birth spacing has significant effect on reducing the rate of early neonatal and neonatal mortality. Therefore, there must be a minimum interval of 24 months between two consecutive pregnancies to reduce risks.

Keywords: Birth spacing, Neonatal mortality, Kaplan-Meier estimator, weighted log-rank test, weighted Cox proportional hazard regression model.

Mathematics Subject Classification: 62N02.

1. Introduction

Numerous studies were conducted around the world to determine the effect of birth spacing on infant mortality. Two of the earliest studies by Hughes (1923) and Woodbury (1925) showed that short preceding birth intervals resulted in higher infant mortality rates. Eastman (1944) studying births occurring at Johns Hopkins University Hospital from 1936 to 1943 found that only very short birth intervals, less than 12 months, had any effect on children or mothers. Yerushalmy (1945) found that relatively short intervals and relatively long intervals are associated with higher stillbirth rates and that the moderate intervals lead to the lowest rates.

A comprehensive investigation of the effect of multiple birth intervals, including preceding and subsequent intervals was done by Hobcraft, McDonald, and Rutstein (1983). The study was also one of the earliest to control for a series of confounding factors such as prior deaths, maternal age, birth order, and socio-economic status. Rutstein (2005a) also presents a summary of several studies related to effect of birth intervals on neonatal, infant and under-five years mortality in the US and other developing countries.

Despite substantial progress in child survival in Bangladesh, the success has been mostly preventing deaths of older children. Children under the age of one, particularly neonates who are new-borns, face significant challenges to survive. Many neonates die within their first week of life i.e., in early neonatal period. (BDHS 2014)

Various studies were done since the 1980s using data from the Matlab, Bangladesh Demographic Surveillance project. In a prospective cohort research, Koenig et al. (1990) discovered that birth interval effects were concentrated in early infancy for those born earlier and in early childhood for those born later (ages 1 to 4 years). This study took into account the child's sex, the mother's age, the child's birth order, the mother's education, the housing area, the death of the previous child, and time.

Several research report that birth spacing effects on mortality are stronger in the post-neonatal than in the neonatal period (Curtis *et al*, 1993; Hobcraft *et al*, 1985; Swenson, 1981). A study by Alam N. (1995) found that with the exception of the neonatal period, birth spacing effects were highly significant.

"A comprehensive analysis used pooled data on over one million births from 52 Demographic and Health Surveys (DHSs) (Rutstein, 2008). A large number of potential confounders were controlled in multivariate modelling, including intendedness of the child, mother's use of health services and contraception, socioeconomic factors, and maternal age and parity. The adjusted results implied that children born within 24 months of an elder sibling experienced a 60% increased risk of death in infancy while those born within two to three years faced a 10% increase compared with those born after intervals of four to five years. This result is broadly consistent with earlier cross-national studies using similar data sources (Hobcraft *et al.*, 1985; UN, 1994; Rutstein *et al.*, 2005b)" (Fotso et. al, 2012).

Regarding early child mortality (between ages one and five years), most studies show significant adverse effects of short preceding intervals, but they are less pronounced than in infancy.

This paper attempts to assess the effect of birth spacing on early neonatal mortality, neonatal mortality and infant mortality in survival analysis using BDHS 2014 survey data. Evidently, the most used methods for estimation and group comparison of survival curves are Kaplan-Meier estimator (Kaplan and Meier, 1958) and log-rank test (Kleinbaum, 2005). Another frequently used method in survival analysis is Cox proportional hazard regression model (Cox, 1972), which is analogous to a multiple regression model and enables the difference between survival times of particular groups of individuals while allowing for other factors. However, in the presence of confounding, the Kaplan-Meier estimates of survival functions may be biased. Propensity score methods are commonly applied to neutralize this kind of bias.

This study combines the use of propensity score adjusted Kaplan-Meier estimator and weighted log-rank test (Xie and Liu, 2005), as well as Propensity score adjusted and weighted Cox proportional hazard regression model for survival analysis.

1.1 Objectives of the Study

To explore the true effect of birth spacing and other selected covariates on early neonatal, neonatal and infant mortality, this paper applied

- Kaplan-Meier estimator and Log-rank test,
- Cox proportional hazard regression model,

- propensity score adjusted survival analysis methods (i.e., adjusted Kaplan-Meier estimator and weighted Log-rank test), and
- propensity score adjusted and weighted Cox proportional hazard regression model to find the true hazard ratio comparing birth spacing groups on the mortality events.

2. Data and Variables

The data utilized for this study is extracted from the nationally representative 2014 Bangladesh Demographic and Health Survey (BDHS 2014).

The 2011 Population and Housing Census by the Bangladesh Bureau of Statistics (BBS), served as the survey's sampling frame. The survey's principal sampling unit (PSU) is enumeration areas (EA) designed to include approximately 120 households. An EA is either a village or a group of small villages or a part of large village.

The survey is based on a two-stage stratified sample of households. In the first stage, 600 EAs were selected with probability proportional to the EA size, with 207 EAs in urban areas and 393 in rural areas. A complete household listing operation was then carried out in all of the selected EAs to provide a sampling frame for the second-stage selection of households. In the second stage of sampling, a systematic sample of 30 households on average was selected per EA to provide statistically reliable estimates of key demographic and health variables for the country as a whole, for urban and rural areas separately, and for each of the seven divisions. The survey selected 18,000 (6,210 in urban and 11,790 in rural areas) residential households. All ever-married women of age 15-49 who were usual members of the selected households and those who spent the night before the survey in the selected households are eligible to be interviewed in the survey. The survey is designed to produce representative results for the country as a whole, for the urban and rural areas separately, and for each of the seven administrative divisions or regions.

2.1 Dependent Variables

Three dependent variables based on BDHS 2014 survey were considered, which are *early neonatal mortality*, *neonatal mortality*, and *infant mortality* along with corresponding *Time* variable.

Early neonatal mortality:

$$Censoring\ indicator = \delta_i = \begin{cases} 1, & \text{if a child dies befor age of 7 days} \\ 0, & \text{Otherwise} \end{cases}$$

Neonatal mortality:

$$Censoring\ indicator = \delta_i = \begin{cases} 1, & \text{if a child dies befor age of 28 days} \\ 0, & \text{Otherwise} \end{cases}$$

Infant mortality:

$$Censoring\ indicator = \delta_i = \begin{cases} 1, & \text{if a child dies befor age of 1 year} \\ 0, & \text{Otherwise} \end{cases}$$

Corresponding **Time** variable is defined as

$$Time = T_i = \begin{cases} \text{Age at death for event,} \\ \text{Age at the end of the study for non event} \end{cases}$$

which is formed using the difference between the variable date of interview and date of birth and considered in the data set as 7 days, 28 days or 365 days.

2.2 Treatment Variable

Birth spacing (i.e., the interval between two successive births) is the treatment variable. The variable birth spacing is created by categorizing the variable 'preceding birth interval' into two categories: Short (less than 24 months) and Normal (24 months or above). That is,

$$Birth\ spacing = \begin{cases} \text{Short,} & \text{if PBI} < 24 \text{ months} \\ \text{Normal,} & \text{if PBI} \geq 24 \text{ months} \end{cases}$$

where PBI is the preceding birth interval.

2.3 Covariates

The covariates considered in this study were Place of residence, Region, Mother's education, wealth index, mother's age at birth, access to media, and membership of NGOs.

- Place of residence: This variable has two categories- Rural and Urban.
- Region: Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Rangpur, and Sylhet.
- Mother's education: No education, Primary education, Secondary education, and Higher education.
- Wealth index: Poor, middle and rich.
- Mother's age at birth: below 20, 20 to 30, above 30.
- Access to media: exposure and non-exposure to any of reading newspaper, listening to radio or watching TV.
- Membership of NGO: NGO member (i.e., member of NGOs like Grameen Bank, ASHA, BRDB, Proshika, BRAC) and non-member.

3. Standard Survival Analysis: Effect of Birth Spacing on Survival in Bangladesh

3.1 Kaplan-Meier Estimator and Log-Rank Test

First, the effect of birth spacing on three types of mortality will be investigated using Kaplan-Meier estimator and log-rank tests. Then the same tests will be applied to assess the effects of other covariates on mortality.

Unadjusted Effect of Birth Spacing on Mortality

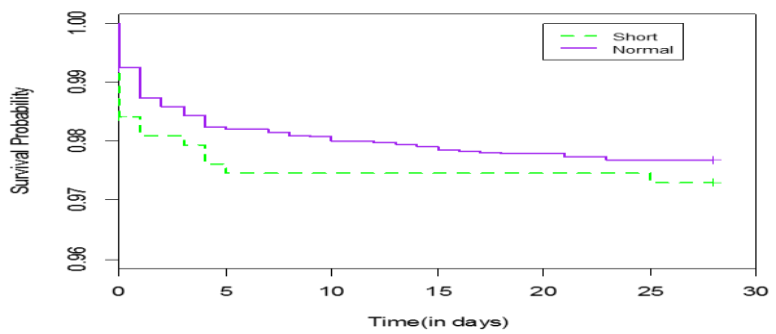


Fig. 3.1: Survival curves of early neonatal mortality by birth spacing (Log-rank test: p-value=0.20)

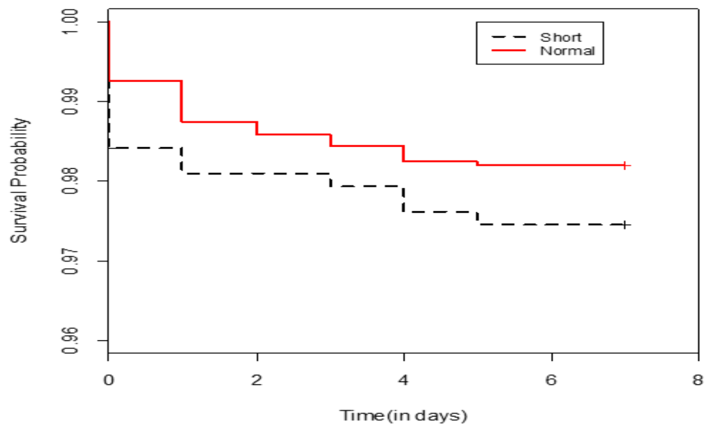


Figure 3.2: Survival curves of neonatal mortality by birth spacing (Log-rank test: p-value=0.54)

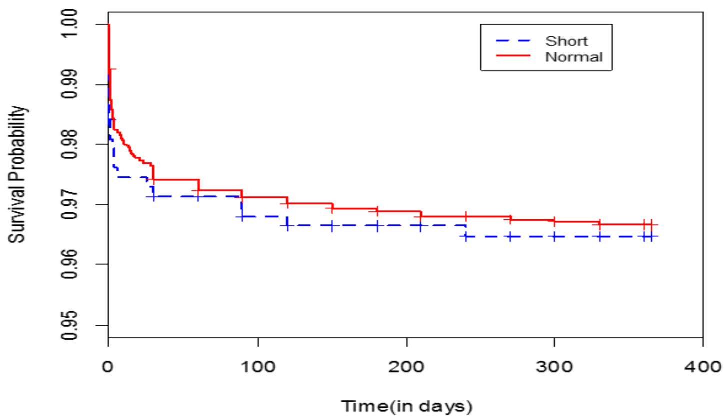


Figure 3.3: Survival curves of infant mortality by birth spacing (Log-rank test: p-value=0.78)

Log-rank test and p-value show that birth spacing has no significant effect on early neonatal, neonatal and infant mortality.

Unadjusted Effect of Other Selected Covariates on Infant Mortality

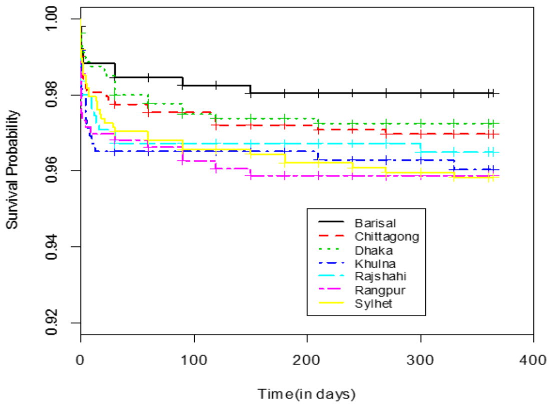


Figure 3.4: Survival curves by region
(Log-rank test: p-value=0.27)

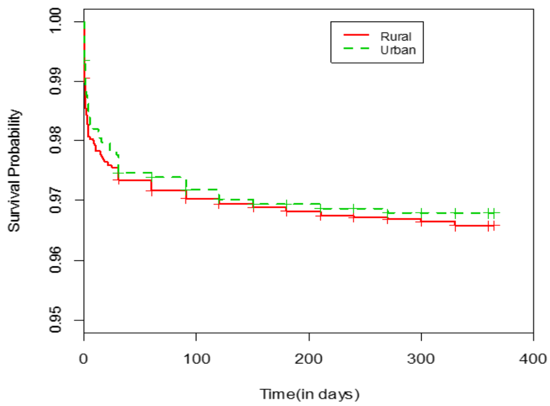


Figure 3.5: Survival curves by place of residence
(Log-rank test: p-value=0.73)

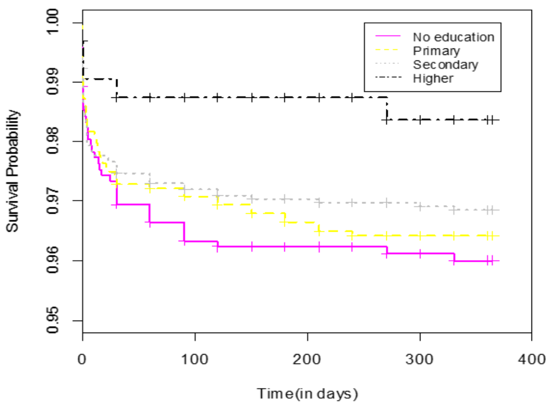


Figure 3.6: Survival curves by mother's education
(Log-rank test: p-value=0.20)

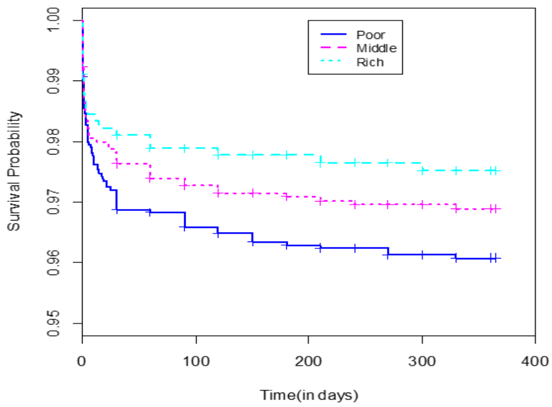


Figure 3.7: Survival curves by wealth index
(Log-rank test: p-value=0.11)

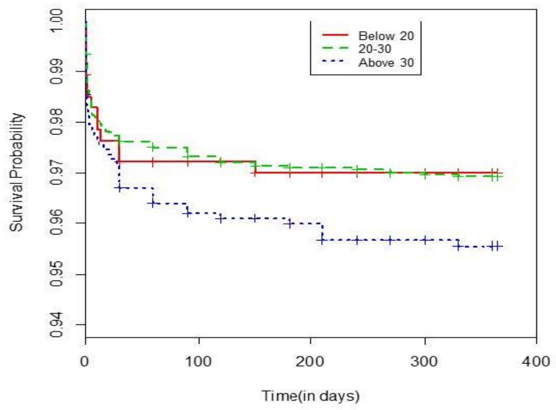


Figure 3.8: Survival curves by mother's age at birth (Log-rank test: p-value=0.09)

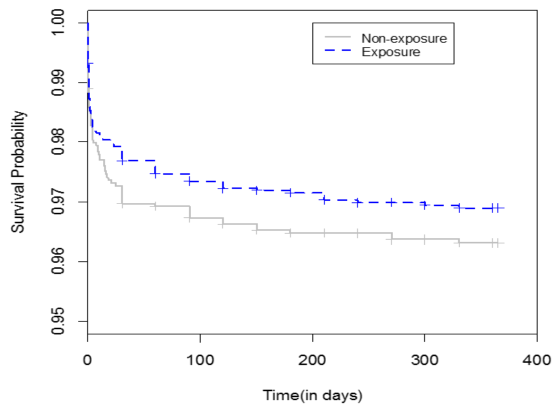


Figure 3.9: Survival curves by access to media (Log-rank test: p-value=0.26)

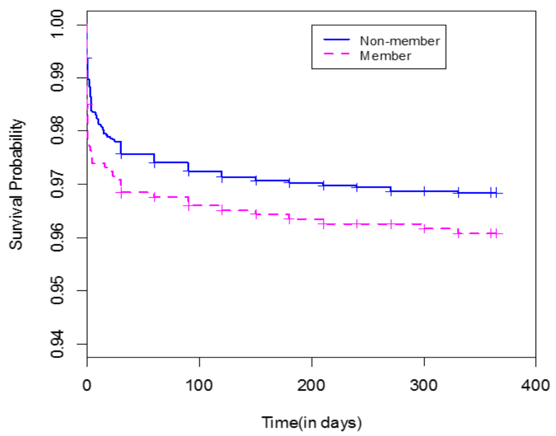


Figure 3.10: Survival curves by membership of NGO

(Log-rank test: p-value=0.19)

In case of early neonatal mortality, *membership of NGO* shows significant effect whereas, in case of neonatal and infant mortality *region* and *mother's age at birth* show significant effect respectively.

4. Effect of Birth Spacing on Mortality under Multivariate Setup

The log-rank test offers a p-value for the group differences but no estimate of the actual effect. Cox proportional hazard (PH) regression model is used to assess several factors simultaneously, and also estimates the effect for each constituent factor.

Table 4.1: Cox proportional hazard regression estimates of covariates for early neonatal mortality

Variables	Category	coefficient	Hazard Ratio	Se (coef)	p-value
Birth spacing	Short (RC)	-	-	-	-
	Normal	-0.451	0.637	0.291	0.121
Region	Barisal	0.056	1.057	0.534	0.917
	Chittagong	0.539	1.714	0.410	0.188
	Dhaka (RC)	-	-	-	-
	Khulna	0.982	2.669	0.431	0.023*
	Rajshahi	0.632	1.881	0.454	0.164
	Rangpur	0.979	2.660	0.425	0.021*
	Sylhet	0.416	1.516	0.422	0.325
Place of residence	Rural (RC)	-	-	-	-
	Urban	-0.078	0.925	0.264	0.767
Mother's education	No education (RC)	-	-	-	-
	Primary	-0.011	0.989	0.304	0.970
	Secondary	0.085	1.089	0.312	0.784
	Higher	-0.782	0.458	0.652	0.231
Wealth index	Poor	0.230	1.258	0.330	0.486
	Middle (RC)	-	-	-	-
	Rich	-0.332	0.717	0.340	0.327
Mother's age at birth	Below 20 years	-0.250	0.779	0.393	0.525
	20-30 years (RC)	-	-	-	-
	Above 30 years	0.247	1.280	0.259	0.341
Access to media	Exposure	-0.070	0.933	0.267	.795
	Non-exposure (RC)	-	-	-	-

Significance level: ***p=0.0, **p<0.01, *p<0.05, +p<0.10, RC=Reference Category

Table 4.2: Cox proportional hazard regression estimates of covariates for neonatal mortality

Variables	Category	coefficient	Hazard Ratio	se (coef)	p-value
Birth spacing	Short (RC)	-	-	-	-
	Normal	-0.173	0.841	0.278	0.533
Region	Barisal	-0.289	0.748	0.506	0.567
	Chittagong	0.382	1.465	0.366	0.296
	Dhaka (RC)	-	-	-	-
	Khulna	0.893	2.442	0.381	0.019*
	Rajshahi	0.703	2.019	0.386	0.068^{+}
	Rangpur	0.713	2.041	0.384	0.063^{+}
	Sylhet	0.522	1.685	0.359	0.146
Place of residence	Rural	-	-	-	-
	Urban	0.022	1.022	0.237	0.926
Mother's education	No education (RC)	-	-	-	-
	Primary	0.045	1.046	0.261	0.861
	Secondary	0.021	1.021	0.278	0.941
	Higher	-0.896	0.408	0.636	0.159
Wealth index	Poor	0.368	1.444	0.300	0.220
	Middle (RC)	-	-	-	-
	Rich	-0.325	0.723	0.318	0.308
Mother's age at birth	Below 20 years	-0.047	0.954	0.337	0.888
	20-30 years (RC)	-	-	-	-
	Above 30 years	0.253	1.288	0.231	0.273
Access to media	Exposure	-0.168	0.845	0.238	0.480
	Non-exposure (RC)	-	-	-	-

Table 4.3: Cox proportional hazard regression estimates of covariates for infant mortality

Variables	Category	coefficient	Hazard Ratio	Se (coef)	p-value
Birth spacing	Short (RC)	-	-	-	-
	Normal	-0.085	0.919	0.242	0.726
Region	Barisal	-0.371	0.690	0.387	0.337
	Chittagong	0.129	1.138	0.286	0.652
	Dhaka (RC)	-	-	-	-
	Khulna	0.414	1.513	0.316	0.190
	Rajshahi	0.269	1.308	0.317	0.397
	Rangpur	0.431	1.539	0.305	0.157
	Sylhet	0.355	1.426	0.275	0.197
Place of residence	Rural	-	-	-	-
	Urban	0.049	1.050	0.198	0.806
Mother's education	No education (RC)	-	-	-	-
	Primary	0.024	1.024	0.218	0.913
	Secondary	-0.029	0.972	0.234	0.901
	Higher	-0.790	0.454	0.499	0.114
Wealth index	Poor	0.424	1.528	0.256	0.098^{+}
	Middle (RC)	-	-	-	-
	Rich	-0.286	0.751	0.269	0.287
Mother's age at birth	Below 20 years	-0.082	0.921	0.297	0.783
	20-30 years (RC)	-	-	-	-
	Above 30 years	0.409	1.506	0.187	0.028*
Access to media	Exposure	0.006	1.006	0.202	0.977
	Non-exposure (RC)	-	-	-	-

Cox proportional hazard (PH) regression model shows that birth spacing has no significant effect on early neonatal, neonatal and infant mortality. Regional effects of Khulna and Rangpur are significant on early neonatal and neonatal mortality. In case of infant mortality, the effect of the variables *wealth index* and *mother's age at birth* are found to be significant.

It is suspected that the insignificant associations between birth spacing and mortality obtained under bivariate (Kaplan-Meier estimator and log-rank test) and multivariate setup (Cox PH model) may not be the true scenario, since the treatment variable birth spacing may be related to other factors (sometimes called pre-treatment variables) such as place of residence, mother's education, mother's age at birth, wealth index etc., rather the effect of other factors may have distorted the true associations between birth spacing and mortality.

5. Propensity Score Adjusted Survival Analysis: True Effect of Birth Spacing on Survival in Bangladesh

A popular way to adjust the effect of pre-treatment variables on treatment variable is to use propensity score. The propensity score analysis first check whether the treatment variable is associated with pre-treatment variables. If they are, propensity score method is used to balance it. When balance is achieved, standard analysis is used to examine the treatment-outcome relationship (i.e., true association), since after propensity score adjustment treatment variable is no longer associated with pre-treatment variables.

5.1 Propensity Score estimation and Covariate Balance

The common approach for calculating propensity score is logistic regression model, where the dependent variable is birth spacing and the independent variables are all measured covariates: place of residence, region, mother's age at birth, wealth index, mother's education, membership of NGO, access to media. From this fitted logistic regression model, propensity score, $p_i = (X_i = 1|Z_i)$, will be obtained where X_i is the treatment indicator and Z_i is the vector of observed covariates. The probability of treatment p will be calculated without considering covariates, where

$$p = p(X = 1) = \frac{Total\ number\ of\ individuals\ in\ treatment\ group}{Total\ number\ of\ individuals}$$

This estimated propensity score p_i, the unconditional probability p and treatment indicator X is used to calculate two different weights namely W_1 and W_2 for inverse probability weighting (IPW) analysis.

$$w_1 = \frac{x}{p_i} + \frac{(1-X)}{(1-p_i)}\ ,$$

$$w_2 = X\frac{p}{p_i} + (1-X)\frac{1-p}{1-p_i}\ .$$

Then these weights and conduct weighted bivariate analysis is used to see whether covariate balance has been achieved. These weighted bivariate results are shown in Table 5.1 along with the unweighted results.

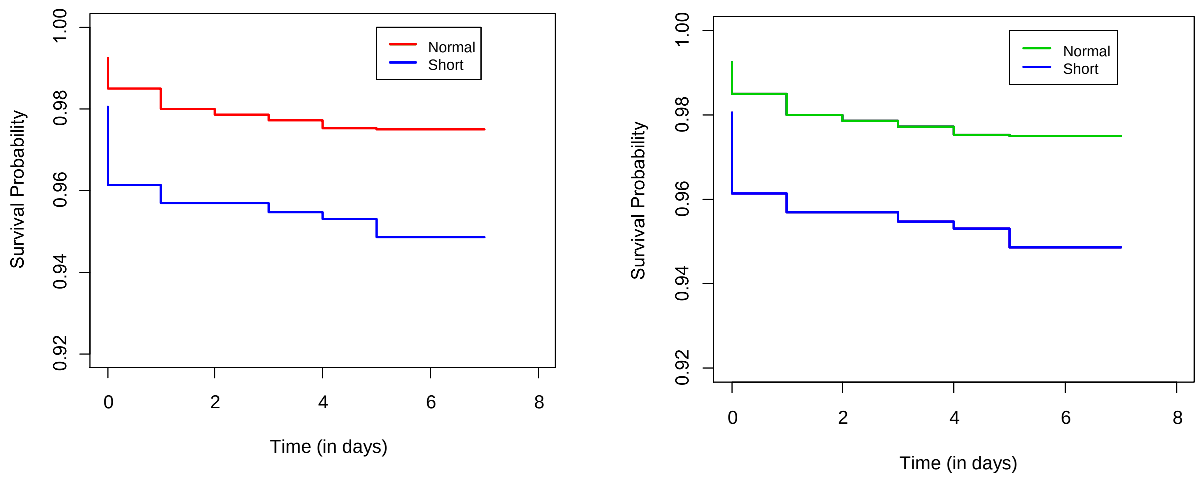
Table 5.1: Assessment of covariate balance through IPW based on propensity score

	Variables	**Birth spacing**		**p-value**
		Short Count (%)	**Normal Count (%)**	
	Place of residence			
Unweighted	Urban	167 (12.0%)	1228 (88.0%)	0.099
(Total=4770)	Rural	464 (13.7%)	2911 (86.3%)	
W_1	Urban	1397 (50.0%)	1395 (50.0%)	0.551
(Total=9466)	Rural	3294 (49.4%)	3379 (50.6%)	
W_2	Urban	185 (13.3%)	1211 (86.7%)	0.775
(Total=4762)	Rural	436 (12.9%)	2932 (87.1%)	
	Mother's age at birth			
Unweighted	Below 20	191 (40.6%)	279 (59.4%)	0.000
(Total=4770)	20-30	360 (11.0%)	2906 (89.0%)	
	Above 30	80 (7.7%)	954 (92.3%)	
	Below 20	481 (50.3%)	475 (49.7%)	0.364
	20-30	3250 (49.9%)	3266 (50.1%)	
	Above 30	960 (48.2%)	1033 (51.8%)	
	Below 20	64 (13.4%)	412 (86.6%)	0.784
	20-30	430 (13.2%)	2834 (86.8%)	
	Above 30	127 (12.4%)	897 (87.6%)	
	Wealth index			
Unweighted	Poor	315 (14.6%)	1845 (85.4%)	0.031
(Total=4770)	Middle	116 (12.8%)	789 (87.2%)	
	Rich	200 (11.7%)	1505 (88.3%)	
W_1	Poor	2207 (50.5%)	2167 (49.5%)	0.153
(Total=9466)	Middle	828 (47.8%)	906 (52.2%)	
	Rich	1656 (49.3%)	1702 (50.7%)	
W_2	Poor	292 (13.4%)	1880 (86.6%)	0.632
(Total=4762)	Middle	109 (12.2%)	786 (87.8%)	
	Rich	219 (12.9%)	1476 (87.1%)	
	Mother's education			
Unweighted	No education	131 (12.9%)	888 (87.1%)	0.304
(Total=4770)	Primary	217 (14.6%)	1269 (85.4%)	
	Secondary	243 (12.5%)	1702 (87.5%)	
	Higher	40 (12.5%)	280 (87.5%)	
W_1	No education	999 (49.5%)	1020 (50.5%)	0.894
(Total=9465)	Primary	1497 (50.1%)	1490 (49.9%)	
	Secondary	1883 (49.2%)	1946 (50.8%)	
	Higher	311 (49.4%)	319 (50.6%)	
W_2	No education	132 (13.0%)	885 (87.0%)	0.986
(Total=4763)	Primary	198 (13.3%)	1293 (86.7%)	
	Secondary	249 (12.8%)	1689 (87.2%)	
	Higher	41 (12.9%)	276 (87.1%)	
	Membership of NGO			
Unweighted	Member	155 (12.2%)	1117 (87.8%)	0.200
(Total=4770)	Non-member	476 (13.6%)	3022()	
W_1	Member	1271 (50.0%)	1271 (50.0%)	0.601
(Total=9466)	Non-member	3420 (49.4%)	3504 (50.6%)	
W_2	Member	168 (13.2%)	1103 (86.8%)	0.804
(Total=4763)	Non-member	452 (12.9%)	3040 (87.1%)	
	Access to media			
Unweighted	Exposure	323 (12.1%)	2345 (87.9%)	0.010
(Total=4770)	Non-exposure	308 (14.7%)	1794 (85.3%)	
W_1	Exposure	2580 (49.2%)	2665 (50.8%)	0.426
(Total=9466)	Non-exposure	2110 (50.0%)	2110 (50.0%)	
W_2	Exposure	341 (12.9%)	2312 (87.1%)	0.707
(Total=4763)	Non-exposure	279 (13.2%)	1831 (86.8%)	

5.2 Propensity Score Adjusted Kaplan-Meier Estimator and Weighted Log-Rank Test

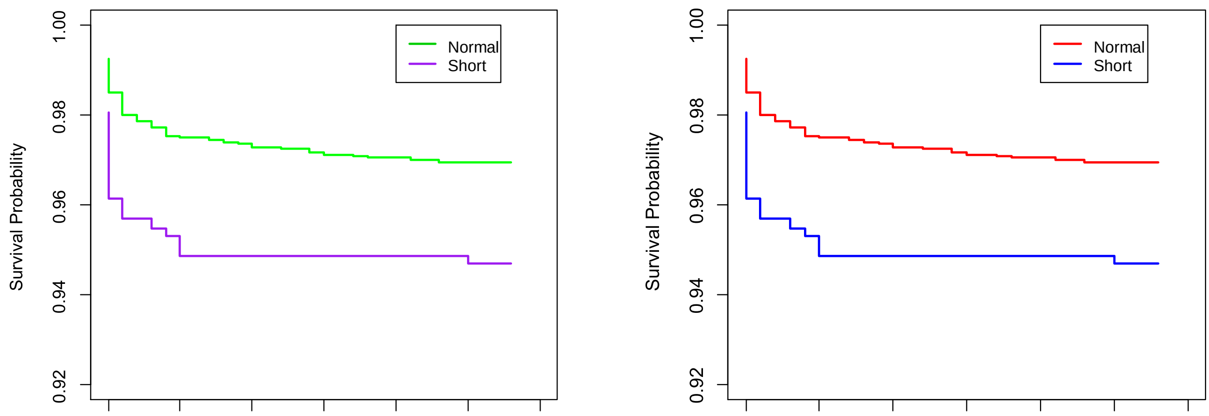
5.2.1 True Effect of Birth Spacing on Mortality

The variable birth spacing has two categories: Short and Normal. To examine the true effect of birth spacing on mortality, the propensity score adjusted Kaplan-Meier estimator and the weighted log-rank test are applied to the data.



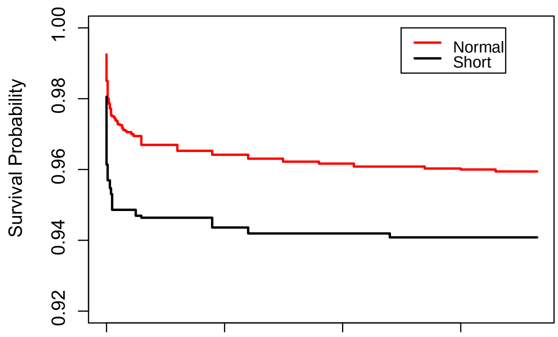
(a) (b)

Figure 5.1: Survival curves of early neonatal mortality by birth spacing: (a) Weight=W_1 and p-value= 0.025; (b) Weight= W_2 and p-value =0.022

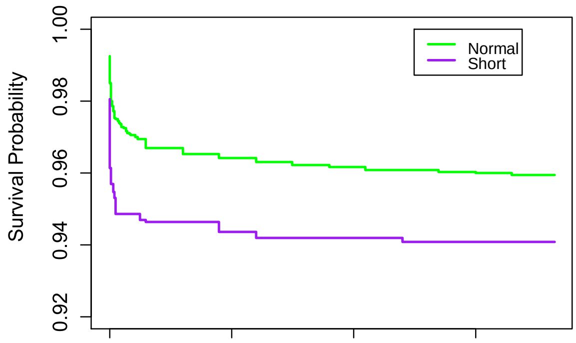


(a) (b)

Figure 5.2: Survival curves of neonatal mortality by birth spacing: (a) Weight=$W1$ and p-value = 0.13; (b) Weight= W_2 and p-value =0.11



(a)



(b)

Figure 5.3: Survival curves of infant mortality by birth spacing: (a) Weight=W_1 and p-value = 0.38; (b) Weight= W_2 and p-value =0.35

In case of early neonatal deaths, the adjusted Kaplan-Meier estimates and weighted log rank test shows that the survival probabilities are lower for babies for whom birth spacing is short. The p-value of weighted log-rank test is 0.025 (when weight=W_1), which indicates that the result is significant. When weight W_2 is used, similar result is found with weighted log-rank test p-value 0.022. Therefore, birth spacing has significant impact on early neonatal mortality.

For neonatal deaths and infant deaths, adjusted Kaplan-Meier estimator and weighted log-rank test did not find any significant association between birth spacing and neonatal and infant mortality.

6. Propensity Score and Covariate Adjusted True Effect of Birth Spacing on Survival

Cox proportional hazard regression model is used to determine the effect of birth spacing in the presence of other covariates, with the weights W_1 and W_2, to find the propensity score and covariate adjusted true effect of birth spacing on survival. Birth spacing is included as an independent variable along with other covariates.

6.1 True Effect of Birth Spacing on Early Neonatal Deaths: Cox PH Model

Table 6.1: True effect of birth spacing on early neonatal mortality by Cox PH model

Variables	W_1		W_2	
	Coefficient	**Hazard Ratio**	**Coefficient**	**Hazard Ratio**
Birth spacing	-	-	-	-
Short (RC)				
Normal	-0.623	0.536***	-0.627	0.534*
Region				
Barisal	0.243	1.275	0.153	1.165
Chittagong	-0.106	0.899	0.364	1.440
Dhaka (RC)	-	-	-	-
Khulna	0.773	2.166**	0.911	2.487*
Rajshahi	0.222	1.248	0.584	1.792
Rangpur	0.508	1.661*	0.900	2.461*
Sylhet	-0.341	0.711	0.299	1.350

Variables	W_1		W_2	
	Coefficient	Hazard Ratio	Coefficient	Hazard Ratio
Place of residence				
Rural (RC)	-	-	-	-
Urban	-0.420	0.657*	-0.139	0.870*
Mother's education				
No education (RC)	-	-	-	-
Primary	-0.340	0.712*	-0.130	0.878*
Secondary	-0.864	0.421***	-0.115	0.891*
Higher	-0.950	0.387**	-0.942	0.389+
Wealth index				
Poor	0.347	1.415	0.256	1.293
Middle (RC)	-	-	-	-
Rich	-0.413	0.662	-0.468	0.626
Mother's age at birth				
Below 20	-0.195	0.823	-0.139	0.870
20-30(RC)	-	-	-	-
Above 30	0.571	1.769***	0.312	1.367
Access to media				
Exposure	-0.419	0.658*	-0.061	0.941*
Non-exposure (RC)	-	-	-	-

Significance level: ***p=0.0, **p<0.01, *p<0.05, +p<0.10, RC=Reference category

In case of W_1, it is observed that babies with normal birth spacing have 46.4% less rate of early neonatal mortality than those babies with short birth spacing. This finding is highly significant since p-value is less than 0.00.

In case of W_2, the hazard ratio for babies with normal birth spacing is 0.534. That is, babies with normal birth spacing have 46.6% less rate of early neonatal mortality than those babies with short birth spacing. This result is significant at 5% level of significance.

Table 6.2: True effect of birth spacing on neonatal mortality by Cox PH model

Variables	$W1$		W_2	
	Coefficient	Hazard Ratio	Coefficient	Hazard Ratio
Birth spacing				
Short (RC)	-	-	-	-
Normal	-0.409	0.664**	-0.413	0.662+
Region				
Barisal	0.168	1.183	-0.133	0.875
Chittagong	0.021	1.021	0.245	1.278
Dhaka (RC)	-	-	-	-
Khulna	0.808	2.244***	0.879	2.411*
Rajshahi	0.369	1.446	0.721	2.057+
Rangpur	0.423	1.526*	0.675	1.963+
Sylhet	-0.177	0.837	0.449	1.567
Place of residence				
Rural (RC)	-	-	-	-
Urban	-0.352	0.703*	-0.042	0.959*

Variables	$W1$		W_2	
	Coefficient	Hazard Ratio	Coefficient	Hazard Ratio
Mother's education				
No education (RC)	-	-	-	-
Primary	-0.374	0.688*	-0.045	0.956+
Secondary	-0.938	0.392***	-0.166	0.847*
Higher	-1.055	0.348**	-1.032	0.356+
Wealth index				
Poor	0.478	1.613*	0.405	1.499
Middle (RC)	-	-	-	-
Rich	-0.772	0.462	-0.465	0.628
Mother's age at birth				
Below 20	-0.076	0.927	0.069	1.071
20-30(RC)	-	-	-	-
Above 30	0.483	1.621***	0.297	1.346
Access to media				
Exposure	-0.430	0.650*	-0.159	0.853+
Non-exposure (RC)	-	-	-	-

For neonatal deaths, in case of W_1, it is observed from Cox PH model that, the babies with normal birth spacing have 33.6% less rate of neonatal mortality than those babies for whom birth spacing is short. This finding is highly significant since p-value is less than 0.01.

In case of W_2, it is found that babies with normal birth spacing have 33.8% less rate of neonatal mortality than those babies with short birth spacing. This result is significant at 10% level of significance.

Table 6.3: True effect of birth spacing on infant mortality by Cox PH model

Variables	W_1		W_2	
	Coefficient	Hazard Ratio	Coefficient	Hazard Ratio
Birth spacing				
Short (RC)	-	-	-	-
Normal	-0.213	0.808+	-0.222	0.801
Region				
Barisal	0.026	1.026	-0.218	0.804
Chittagong	0.027	1.027	0.073	1.076
Dhaka (RC)	-	-	-	-
Khulna	0.540	1.717**	0.464	1.591
Rajshahi	0.150	1.162	0.345	1.412
Rangpur	0.297	1.346	0.462	1.586
Sylhet	0.066	1.069	0.344	1.410
Place of residence				
Rural (RC)	-	-	-	-
Urban	-0.315	0.730*	-0.013	0.987
Mother's education				
No education (RC)	-	-	-	-
Primary	-0.299	0.741*	-0.053	0.949
Secondary	-0.735	0.479***	-0.179	0.836*
Higher	-0.935	0.392**	-0.834	0.434+
Wealth index				
Poor	0.587	1.798**	0.450	1.569+

Variables	W_1		W_2	
	Coefficient	Hazard Ratio	Coefficient	Hazard Ratio
Middle (RC)	-	-	-	-
Rich	-0.352	0.703*	-0.385	0.680
Mother's age at birth				
Below 20	-0.076	0.927	0.011	1.011
20-30 (RC)	-	-	-	-
Above 30	0.492	1.636***	0.419	1.520*
Access to media				
Exposure	-0.301	0.740*	-0.005	0.995
Non-exposure (RC)	-	-	-	-

In case of W_1, for babies whose birth spacing is normal the hazard ratio is 0.808 for infant deaths. Meaning, babies with normal birth spacing have 19.2% less rate of infant mortality than those babies with short birth spacing. The result is significant at 10% level of significance.

In case of W_2, the hazard ratio for babies with normal birth spacing is 0.801. That is, babies with normal birth spacing have 19.9% less rate of infant mortality than those babies with short birth spacing. But the result is not significant. In practice, Cox PH model with stabilized weight provides better results (Cole and Hernan, 2004). W_2 is the stabilized weight, so from the results of Cox PH model it can be concluded that birth spacing has no significant effect on infant mortality.

7. Conclusion

This study finds that though birth spacing has no significant effect on infant mortality, it has significant effect on early neonatal mortality and neonatal mortality. It is observed that if birth spacing is less than 24 months then the rate of early neonatal and neonatal mortality increases. Therefore, this research concludes that the minimum interval before attempting the next pregnancy should be at least 24 months to reduce the risk of adverse maternal, perinatal and infant outcomes. The policy makers should make people aware of this recommended birth spacing of at least 24 months, which is beneficial for the children and mothers' health.

References

[1] Alam, N. (1995). Birth spacing and infant and early childhood mortality in a high fertility area of Bangladesh: age-dependent and interactive effects. Journal of Biological Science; 27(4):393 – 404.

[2] Bangladesh Demographic and Health Survey, (BDHS 2014). NIPORT, Dhaka, Bangladesh; Mitra and Associates, Dhaka, Bangladesh.

[3] Cole, S. R. and Hernan,` M. A. (2004). Adjusted Survival Curves with Inverse Probability Weights. Computer Methods and Programs in Biomedicine, 75, 45-49.

[4] Cox, D. R. (1972). Regression models and life-tables (with discussion). Journal of the Royal Statistical Society, Series B, 24, 187-220.

[5] Curtis, S. L., Diamond, I. D. and Mcdonald, J. W. (1993). Birth interval and family effects on postneonatal mortality in Brazil. Demography; 30, 33.

[6] Eastman, N. J. (1944). The effect of the interval between births on maternal and fetal outlook. American Journal of Obstetrics and Gynaecology; 47 (4): 445-466.

[7] Fotso, J. C., Cleland, J., Mberu, B., Mutua, M., and Elungata, P. (2012). Birth spacing and child mortality: an analysis of prospective data from the Nairobi urban health and demographic surveillance system. Journal of Biosocial Science, 45, 779–798.

[8] Hobcraft, J., McDonald J. and Rutstein S.O. (1983). Child-spacing effects on infant and early child mortality. Population Index 1983; 49(4)585 – 618.

[9] Hobcraft, J., McDonald, J. and Rutstein, S.O. (1985). Demographic determinants of infant and early childhood mortality. Population Studies; 39:363– 385.

[10] Hughes, E. (1923). Infant Mortality. Children's Bureau Publication no. 112 (Washington, D.C.: Government Printing Office).

[11] Kaplan, E. L. and Meier, P. (1958). Nonparametric estimation from incomplete observations. Journal of the American Statistical Association ; 53:457–481.

[12] Koenig, M., Phillips, J. A., Campbell, O.M. and D'Souza, S. (1990). Birth intervals and childhood mortality in rural Bangladesh. Demography; 27(2): 251 – 265.

[13] Rutstein, S. O. (2005a). Effects of preceding birth intervals on neonatal, infant and under-five years mortality and nutritional status in developing countries: evidence from the demographic and health surveys. International Journal of Gynaecology and Obstetrics, 89, S7—S24

[14] Rutstein, S. O., Johnson, K., Conde-Agudelo, A. and Rosas-Bermudez, A. (2005b). Effect of birth spacing on infant and child mortality: a systematic review and meta-analysis. In World Health Organization Consultation and Scientific Review of Birth Spacing. WHO, Geneva, 13–15th, June 2005.

[15] Rutstein, S. O. (2008). Further evidence of the effects of preceding birth intervals on neonatal, infant, and under-five-years mortality and nutritional status in developing countries: evidence from the demographic and health surveys. DHS Working Papers Series.

[16] Swenson, I. (1981). Relationships between pregnancy spacing, sex of infants, maternal age and birth order, and neonatal and post-neonatal mortality in Bangladesh. Social Biology; 28, 299

[17] U. N. (United Nations) (1994). The Health Rationale for Family Planning: Timing of Births and Child Survival. Department for Economic and Social Information and Policy Analysis, Population Division, United Nations, New York.

[18] Woodbury, R. N. (1925). Causal Factors in Infant Mortality. Children's Bureau Publication no. 142 (Washington, D.C.: Government Printing Office).

[19] Xie, J. and Liu, C. (2005). Adjusted Kaplan–Meier estimator and log-rank test with inverse probability of treatment weighting for survival data. Statistics in Medicine; 24(20):3089–3110.

[20] Yerushalmy, J. (1945). On the interval between successive births and its effect on survival of infant. Human Biology; 17(2):65–106.