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Examining infant and child death clustering among families in the cross-sectional and nationally representative Bangladesh Demographic and Health Survey 2017–2018

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ABSTRACT

Objectives We aim to examine the phenomenon of infant and child death clustering while considering the unobserved heterogeneity (frailty) at the family level.

Design, setting, and participants We analysed Bangladesh Demographic and Health Survey 2017–2018 data, including the birth history information for 47 828 children born to 18 134 women. We used Gompertz shared frailty model to control the correlation between event times at the mother level and capture the unobserved risks in infant and child deaths.

Outcome measures We estimated two sets of survival regression models where the failure event is the survival status of the index child during the infancy period, that is, from birth to 11 months, and childhood period, that is, between 12 and 59 months, respectively. All children who died during infancy and childhood were coded as 'yes'; otherwise, they were coded as 'no'.

Results About 2% of mothers experienced two or more infant deaths, and cumulatively these mothers account for 20% of all infant deaths in the sample. Children whose previous sibling was not alive at the time of their conception had 1.86 times (95% CI 1.59 to 2.17) more risk of dying as an infant. However, we did not find a statistically significant effect of death scarring on the risk of child mortality among siblings. Statistically significant frailty effect with a variance of 0.33 (95% CI CI 0.17 to 0.65) and 0.54 (95% CI 0.14 to 2.03)] in infancy and childhood, respectively, indicates the clustering of survival risks within families due to unobserved family-level characteristics shared by the siblings.

Conclusion This study suggests that preceding birth interval, mother's age at first birth and mother's education are the most critical factors which can help in reducing scaring effect on infant mortality. Additionally, women from poor socioeconomic strata should be focused on as still an infant, and child mortality is concentrated among poor households.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Despite the knowledge of infant and child mortality determinants in Bangladesh, some families continue to lose a larger share of children.
⇒ This study explored the correlation between infant and child mortality risks and siblings, considering mother-level unobserved heterogeneity.
⇒ Survival models allow us to take into account censored observations in the retrospective birth history information in Bangladesh Demographic and Health Survey.
⇒ Gompertz shared frailty model shows clustering of survival risks among infants within families due to unobserved family-level characteristics shared by the siblings.

INTRODUCTION

Globally, a substantial decrease in under-5 mortality had occurred from 93 deaths per 1000 live births in 1990 to 38 deaths in 2019.[1] However, constant pressure to improve children's survival persists as many countries lagged behind the target of achieving a two-thirds reduction in child mortality by 2015.[2] Among the under-5 mortality, infant deaths (deaths before 12 months) form the largest part and significantly predict child health progress. In 2019, 5.2 million under-5 deaths were estimated to be occurring from treatable and preventable causes.[3] Among these, 1.5 million deaths were in 1–11 months, 1.3 million were child deaths (deaths between 1 and 4 years) and the remaining 2.4 million deaths accounted for newborns (under 28 days).[3] According to WHO, between 2019 and 2030, about 11 million under-5 deaths can be averted if under-5 deaths are reduced to 25 deaths per 1000 live births in all the countries.[3] More effort is needed in sub-Saharan Africa, and South-east Asian countries as 80% of child deaths originate from them.[3]

With a substantive health policy plan, Bangladesh, a South-east Asian country, has seen a notable increase in the coverage of child survival interventions. Bangladesh registered a remarkable decline in infant mortality

(from 87 deaths per 1000 live births in 1993 to 38 deaths in 2014) and child mortality (from 133 deaths per 1000 live births in 1990 to 30 deaths in 2018) over two decades.[4] So far, studies have brought forward the role of morbidity among children, gender, birth order of the child, birth weight and size of the child, mother's age at birth, mother's education, maternal height and weight, poverty and household wealth, household sanitation facility and residing in rural areas, as factors behind infant and child mortality in Bangladesh.[5–9] Additionally, factors like child immunisation, safe delivery practice and postnatal care were found to influence child mortality.[10 11] Despite these achievements, the country is still lagging in achieving the target of Sustainable Development Goals by 2030. Among the South-east Asian countries, Bangladesh ranks third in child mortality, behind Pakistan (69 deaths per 1000 live births) and India (37 deaths per 1000 live births).[1 12] Interestingly, in Bangladesh, the decline in infant deaths was much slower than those in child deaths.[13] Thus, there is no doubt that, despite the knowledge of such predictors, reduction in infant and child mortality remains to be a significant challenge in Bangladesh.

Besides these determinants, ample evidence from developed and low-income and middle-income countries has shown the occurrence of death clustering in families to be the reason for high infant and child mortality.[14–17] Extensive explanations for death clustering were presented, stating the role of observed and unobserved heterogeneity across families and scaring effect (decrease in survival chance of subsequent children due to death of the older child within a family).[18–20] This phenomenon of correlation of mortality risk among siblings was first brought as a research agenda by Monica Das Gupta in 1990. She had pointed out that child mortality risk was higher among families who have already experienced the loss of other children.[21] A study from Bangladesh provides clear evidence of infant death clustering (the proportion of children who die in infancy is much higher among children whose previous sibling died in infancy than those whose sibling survived). The study shows that infant death is 29% higher if the previous sibling had died during infancy.[7] Arulampalam and Bhalotra had provided the possible mechanism of scaring as depression (a child's death can leave the mother depressed and uncaring, thereby affecting the health of the next child) and replacement hypothesis (the urge to replace a child as sooner as possible, thereby resulting in low birth spacing between subsequent children) as explanations of death clustering in children.[20]

Different approaches to explain the clustering phenomenon were seen in the extant studies, where few studies observed either scarring or unobserved heterogeneity.[7 14 17] However, from the methodological point of view, ignoring the clustering can violate the assumption of independence of event time. Therefore, survival regression models with frailty have been used for analysing the time to event data.[8 22] The term frailty was introduced to represent the unobserved effect shared by subjects with similar risks in mortality, and it takes into account the correlation in infant and child mortality risks with their siblings.[23] Thus, using a shared frailty model, we can control the correlation between event times at the mother level and can capture the unobserved risks in infant and child deaths. So far, quite a few studies have shown the frailty effect of child mortality in Bangladesh,[24] but there is a lack of research exploring the death clustering phenomenon separately for infants (aged between 0 and 11 months) and children (aged between 12 and 59 months). The slower rate of infant mortality reduction has questioned the reliability of studies that focus only on under-5 children or infants, ignoring that these two age brackets (ie, infant and children) may share different levels of correlated mortality risks among siblings. Therefore, using the latest round of Bangladesh Demographic Health Survey, this study examines the phenomenon of infant and child death clustering while taking account the unobserved heterogeneity (frailty) at family level. Further, this study hypothesises that death scarring was associated with infant and child mortality among the children of Bangladesh.

METHODS

Data source

This study used the recently conducted Bangladesh Demographic and Health Survey during 2017–18 (to be referred to as BDHS 2017–2018). To date, eight rounds of DHS have been conducted in Bangladesh, and the BDHS 2017–2018 was conducted by The National Institute for Population Research and Training under the stewardship of the Ministry of Health and Family Welfare of Bangladesh. BDHS 2017–2018 provided crucial information on childhood mortality levels, maternal and child health, fertility and fertility preferences, family planning methods, newborn care, women's empowerment, selected non-communicable diseases, availability and accessibility of health and family planning services in communities. The survey follows a two-stage stratified sampling design. Further details regarding sample design, survey instruments, fieldwork and training of staff, informed consent, data collection and processing, and response rates are available elsewhere.[4]

Study selection and inclusion criteria

This study used the information on complete retrospective birth histories of women in Bangladesh's reproductive age group (15–49 years). In BDHS 2017–2018, the birth history information was available for 47 828 children born to 18 134 women. This study uses the mother as a measure of family interchangeably because the information was collected from one woman of each household. Only singleton births were used for analysis. Therefore, the analytical sample size of this study is 47 095 children born to 18 092 mothers.

We followed the Strengthening the Reporting of Observational Studies in Epidemiology guideline in reporting the study (online supplemental file 1).

Study variables

Outcome variables

We estimated two sets of survival regression models separately. In the first set, the failure event is the survival status of the index child during the infancy period, that is, from birth to 11 months. All children who died during infancy were coded as 'yes'; otherwise, they were coded as 'no'. In the second set, the survival status of the index child during the childhood period, that is, between 12 and 59 months from birth, is the failure event. Again, children who died in childhood were coded as 'yes' and the rest as 'no'.

Explanatory variables

Extant studies have shown that death scarring plays a significant role in infant and child death clustering in families.[14 17] Scarring occurs when the death of the previous sibling affects the survival chances of the index child.[17 19 20] In our study, we measured scarring by a binary variable that denotes the survival status of the preceding sibling during the time of conception of the index child. If the preceding sibling was alive during the time of conception of the index child, then the records were coded as 'alive', and otherwise, they were coded as 'dead'. Taking the survival status of the previous sibling at the time of conception of the index child allows us to understand whether the index child was conceived because of the loss of the preceding child.[19 25]

Potential confounding factors

We also included other child-specific, mother-specific and socioeconomic covariates of infant and child mortality in line with the Mosley-Chen framework of child survival.[26 27] The child-specific covariates are birth interval preceding the index child (less than 19 months, 19–27 months, 28 and more months), birth cohort (1980–1994, 1995–1999, 2000–2004, 2005–2009, 2010–2018), birth order (1–2, 3, 4, 5 and more) and gender (female, male) of the index child, respectively. The mother-specific covariates are the mother's age during birth of the index child (less than 20, 20–24, 25–29, 30 and more), and the mother's level of education (no formal schooling, up to primary, secondary or higher). The socioeconomic covariates are religion of the household/family (Islam, others), place of residence (city corporation, semiurban, rural) and wealth quintile of household (poorest, poorer, middle, richer, richest), respectively. Since infant and child mortality levels vary between Bangladesh's eight administrative divisions (Khulna, Mymensingh, Chattogram, Rangpur, Rajshahi, Dhaka, Barishal, Sylhet), we also controlled for the same. The maternal and socioeconomic covariates included for analysis were assumed to be time-invariant over the mothers' life course.

Statistical analysis

We undertook bivariate and multivariate analyses to realise the objectives of the paper. The bivariate analysis involved examining the distribution of the mothers (or families) by the number of births and number of deaths occurring under those mothers. The multivariate analysis involved estimating parametric survival regression models with shared frailty at the family level (mother level). Using survival models allows us to take into account censored observations in the retrospective birth histories, thereby reducing the loss of crucial information.[15 25 28] However, note that when examining child mortality, we included (42 611 children) only those who came under risk of child mortality at age 12–59 months and excluded (4484 children) who experienced infant deaths or did not complete infancy at the time of interview.

Parametric survival regression models allow us to choose the underlying distribution of time-to-event, that is, the time to infant (or child) mortality. We choose the appropriate model based on theoretical and statistical validation. Statistical measures such as the Akaike information criteria (AIC) and the Bayesian information criteria (BIC) have been widely used in research to determine the goodness of fit of statistical models (refer to references 29 30 for further details). Therefore, we obtained these measures of information criteria for the prominent parametric survival models (Exponential, Weibull, Gompertz, Lognormal and Loglogistic) with frailty at the family level for the infancy (0–11 months), childhood (12–59 months) and under-5 (0–59 months) periods, respectively.

The survival models with family-level frailty assume that the risk of death among children from the same family is correlated due to unmeasured family-related characteristics.[28] The frailty indicator obtained from survival regression models is a positive quantity determined by variance at the family level and is assumed to follow a gamma distribution.[15 25] If the frailty variance is significantly different from zero, it indicates that the risk of mortality of siblings is correlated within families and is affected by unmeasured family-level factors. If the frailty variance is zero, mortality risk does not differ between families. Therefore, a significant frailty effect denotes that the risk of mortality (after adjusting for the effect of explanatory covariates) is higher in some families than others, thereby indicating death clustering among certain families.

HRs determine the adjusted risk of infant and child mortality. The HR for the Gompertz frailty survival model gives the risk of infant (or child) mortality for a particular category of an explanatory variable in comparison to the reference category, given the effect of the remaining explanatory variables as well as the effect of unobserved factors (frailty) at the family-level remain constant.[28] Using the Schoenfeld residual test, we examined the proportional hazard assumption and found that the regression models did not violate the assumption.[28] Additionally, none of the multivariate models violated the assumption of multicollinearity.[31] All statistical estimations were performed using the STATA software V.14.2.[32]

Patient and public involvement

We had no contact with any patients or the public for this study as we used publicly accessible data from the BDHS.

RESULTS

Sample characteristics

We first examine the distribution of births and deaths in our sample by the independent variables. As shown in table 1, out of the 47 095 births, there were 2788 infant deaths and 555 child deaths. Moreover, 22% of children whose previous sibling was not alive at their conception experienced infant mortality. More than half were males among dead infants, and 7 in every 10 were of first-second birth order. Further, 54% and 33% of infant deaths occurred in mothers aged less than 20 years and who had no formal schooling, respectively. Furthermore, 70% of children died before their first birthday in the rural region, and 50% of dead infants belonged to the poorer-poorest wealth quintile households. Moreover, 14% of children in the Sylhet division experienced infant deaths, followed by 13% in the Dhaka and Rajshahi divisions.

Coming to child deaths, we found that 10% of children experienced childhood deaths when their siblings had died by the time of their conception. Further, 51% of female children and 62% of children belonging to the first-second birth order died between their first and fifth birthdays. Among mothers aged less than 20 years and who had no formal schooling, there were 47% and 43% of child deaths, respectively. Further, 69% of rural children and 53% from poorer-poorest households experienced child mortality. Additionally, 18% of children in the Chattogram division experienced child mortality, followed by 16% and 13% in the Barishal and Rajshahi divisions. Further, the survival and mortality experience of the population has been shown in the form of graphs. Figures 1–3 show the survival probability of Bangladeshi children during the under-5 (0–59 months), infancy (0–11 months) and childhood (12–59 months) period, respectively. In all three graphs, we can observe that the hazard of mortality declines with an increase in survival duration.

Model selection

Based on theoretical knowledge and statistical evidence, we use the Gompertz proportional hazard model in our study. The Gompertz regression model is amenable where the hazard of occurrence of the failure event (here, risk of mortality) is either monotonically increasing or decreasing.[28] Based on existing knowledge of human mortality, we know that the risk of mortality is highest in the first month of life, and thereby it decreases persistently until 5 years of age.[14 33–35] We can observe the same in figures 1–3. Moreover, From the results shown in table 2, Gompertz regression models are the best fit for the data in terms of AIC and BIC scores (lowest score), respectively, during infancy, childhood and the under-5 period. Therefore, the above-given arguments justify our use of Gompertz frailty regression models.

The extent of infant and child mortality clustering among mothers/families

A substantial amount of clustering of births and infant deaths among mothers is observed in table 3. Over 44% of mothers have three or more children, subsequently contributing to 66% of children in the sample. Further, we observe that 13% of the mothers experienced infant mortality. Moreover, 2% of mothers experienced two or more infant deaths, and cumulatively, these mothers account for 20% of all infant deaths in the sample.

Similarly, we observe some clustering of births and child deaths among mothers in table 4. We see that 22% of mothers have four or more children, and they accounted for 41% of children in the sample cumulatively. Moreover, 3% of the mothers experienced child mortality and 0.14% of mothers experienced two or more child deaths, accounting for 7% of all child deaths.

Clustering estimates from Gompertz frailty models

Table 5 shows the findings from the Gompertz frailty hazard models for infant mortality and child mortality, respectively. From the hazard models of infant mortality, we observed the Gompertz regression parameter to be statistically significant (see the bottom part of the table) and less than one, thereby implying that the risk of mortality declines from birth till the first birthday. Further, we observed a statistically significant frailty effect with a variance of 0.75 (95% CI 0.60 to 0.95) and 0.33 (95% CI 0.17 to 0.65) in models I and II, respectively. This indicates the clustering of survival risks in infancy and childhood within families due to unobserved family-level characteristics shared by the siblings. Moreover, the statistically significant values of the likelihood ratio test indicate that the Gompertz frailty hazard model is a better fit for the data than standard Gompertz hazard models.

Multivariable association of infant and child mortality with relevant explanatory variables from Gompertz frailty models

Table 5 also gives HRs of the multivariable association of infant and child mortality risk with the explanatory variables after accounting for family-level frailty. Model-II does not include children of first-order births. However, the covariates' association direction is similar in models I and II for infant and child mortality, respectively. In the case of infant mortality, model-II shows that male children have 1.17 times (95% CI 1.05 to 1.30) higher chance of infant death than their female counterparts. Mothers whose age at the time of the index child's birth is less than 20 years have 1.38 times (95% CI 1.20 to 1.60) more significant risk of experiencing infant mortality. We observed that children whose mothers had no formal schooling were 1.30 times (95% CI 1.09 TO 1.54) more likely to die during infancy. Additionally, a birth interval of fewer than 19 months makes the children more vulnerable (HR 2.28; 95% CI 1.96 TO 2.65) to infant mortality.

Table 1 Absolute (N) and percentage (%) distribution of births, infant deaths and child deaths by child-specific, mother-specific and socioeconomic covariates in Bangladesh

	Births		Infant mortality		Child mortality	
Background characteristics	**N**	**%**	**N**	**%**	**N**	**%**
Survival status of previous sibling at the time of conception of index child						
Alive	26337	90.6	1103	77.9	334	90.0
Dead	2729	9.4	313	22.1	37	10.0
Birth interval preceding to index child (in months)						
28 and more months	19993	68.8	663	46.8	181	48.8
19–27 months	5931	20.4	428	30.2	117	31.5
Less than 19 months	3142	10.8	325	23.0	73	19.7
Birth cohort of index child						
2010–2018	13823	29.4	489	17.5	66	11.9
2005–2009	9289	19.7	441	15.8	90	16.2
2000–2004	9070	19.3	504	18.1	96	17.3
1995–1999	7501	15.9	511	18.3	94	16.9
1980–1994	7412	15.7	843	30.2	209	37.7
Birth order of index child						
1–2	31621	67.1	2044	73.3	343	61.8
3	7881	16.7	366	13.1	104	18.7
4	4059	8.6	192	6.9	58	10.5
5 and more	3534	7.5	186	6.7	50	9.0
Gender of index child						
Female	22870	48.6	1207	43.3	283	51.0
Male	24225	51.4	1581	56.7	272	49.0
Mother's age during birth of index child (in years)						
Less than 20	18335	38.9	1516	54.4	261	47.0
20–24	15438	32.8	742	26.6	176	31.7
25–29	8755	18.6	366	13.1	75	13.5
30 and more	4567	9.7	164	5.9	43	7.7
Mother's level of education						
Secondary or higher	18359	39.0	750	26.9	111	20.0
Upto primary	17556	37.3	1130	40.5	206	37.1
No formal schooling	11180	23.7	908	32.6	238	42.9
Religion of the household						
Islam	42919	91.1	2501	89.7	520	93.7
Others	4176	8.9	287	10.3	35	6.3
Place of residence						
City corporation	4175	8.9	212	7.6	53	9.5
Semiurban	11671	24.8	633	22.7	118	21.3
Rural	31249	66.4	1943	69.7	384	69.2
Household wealth quintile						
Richest	8766	18.6	364	13.1	67	12.1
Richer	9079	19.3	531	19.0	81	14.6
Middle	9163	19.5	510	18.3	112	20.2
Poorer	9770	20.7	636	22.8	136	24.5
Poorest	10317	21.9	747	26.8	159	28.6

Continued

Table 1 Continued

Background characteristics	Births		Infant mortality		Child mortality	
	N	%	N	%	N	%
Country administrative division						
Khulna	5375	11.4	283	10.2	38	6.8
Mymensingh	5281	11.2	355	12.7	67	12.1
Chattogram	7304	15.5	347	12.4	98	17.7
Rangpur	5836	12.4	358	12.8	57	10.3
Rajshahi	5522	11.7	364	13.1	73	13.2
Dhaka	6458	13.7	368	13.2	62	11.2
Barishal	5239	11.1	308	11.0	90	16.2
Sylhet	6080	12.9	405	14.5	70	12.6
Overall	47 095	100	2788	100	555	100

Note – (1) The total across all categories of the 'survival status of previous sibling at the time of conception of index child' and 'birth interval preceding to index child (in months)' variables do not add up to the total number of births and deaths as children belonging to first birth order were automatically excluded while calculating the variable.

Notably, children whose previous sibling was not alive at the time of their conception had 1.86 times (95% CI 1.59 TO 2.17) more risk of dying as an infant.

Coming to child mortality, from model-II, we found that male children had 0.74 times (95% CI 0.60 to 0.92) lower risk of child mortality than females. Further, children whose mothers had no formal schooling were 1.27 times (95% CI 0.91 to 1.78) more likely to experience child mortality. Besides, children belonging to the poorest wealth quintile households had 1.93 times (95% CI 1.23 to 3.03) more significant risk of child mortality. Additionally, children born after a birth interval of less than 19 months were 2.24 times (95% CI 1.66 to 3.02) more likely to die between their first and fifth birthdays. However, we did not find a statistically significant effect of death scarring on the risk of child mortality among siblings.

DISCUSSION

Using BDHS, this study had analysed the unequal share of infant and child mortality risks in some families. The analyses show that about 22% and 10% of children whose previous sibling was not alive at their conception experienced infant and child mortality in Bangladesh. Further, the Gompertz shared frailty model at the family level shows a significant correlation in infant mortality risks among the siblings. Children whose previous sibling was not alive at the time of conception were significantly more likely to die as an infant. However, no significant effect of scarring was found among children aged 12–59 months in Bangladesh.

Consistent with the findings of this study, previous research from Nigeria and Bangladesh found that the death of the preceding child was significantly associated

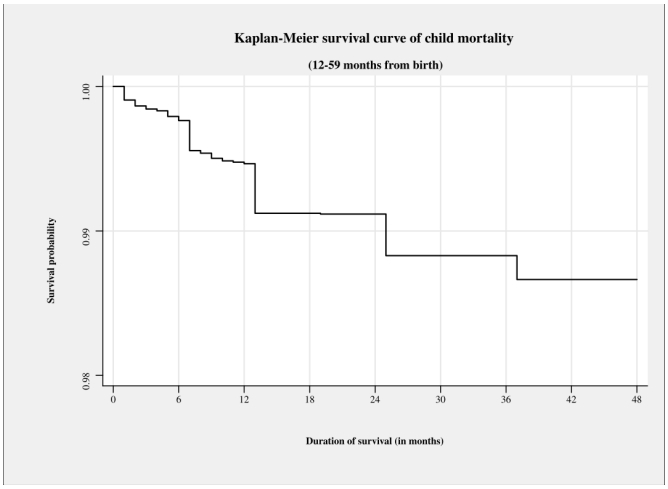

Figure 1 Survival plot for all children in the Bangladesh Demographic and Health Survey 2017–2018 during the under-5 period.

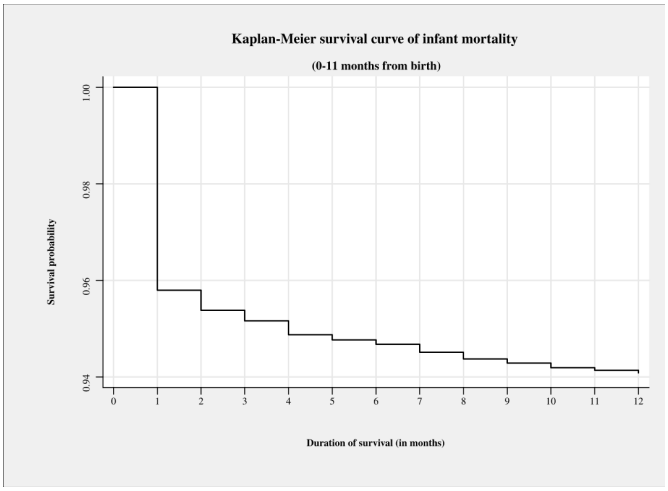

Figure 2 Survival plot for all children in the Bangladesh Demographic and Health Survey 2017–2018 during the infancy period.

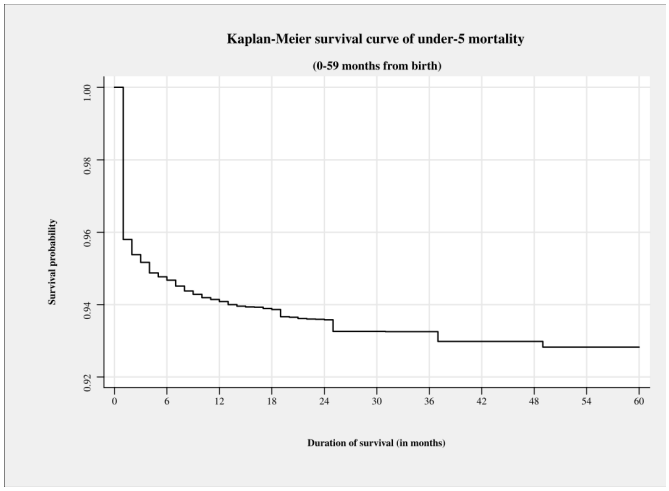

Figure 3 Survival plot for all children in the Bangladesh Demographic and Health Survey 2017–2018 during the childhood period.

with the risk of infant death.[17 36] One of the possible reasons for such a mechanism was the higher prevalence of mortality among regions with higher fertility levels.[37] However, in the case of child mortality, the association with the previous sibling death was not significant in Bangladesh. Earlier research on Kenyan children also found consistent results where it was argued that preceding sibling death was not significantly associated with the death of child after infancy.[15]

Past evidence shows that the death of the preceding child may cause deterioration of the mother's mental health and hence may lead to more births in future with short birth intervals.[38] Additionally, depression and poor mental health among mothers lead to low birth weight among infants, small gestational age and preterm deliveries which again increases the risk of infant mortality.[39] Poor mental health among mothers after child loss may affect the health of the child before birth and after birth. Depression and poor mental health may lead to the adaptation of poor dietary habits among mothers and their newborn babies, thereby increasing the risk of infant loss.[39] This causes the scarring effect to be significant in the case of infant mortality (0–11 months) and not significant in the case of child mortality (12–59 months). Additionally, previous studies had found similar results that infant and child death clustering still exists in every region; however, the magnitude may differ significantly.[16 17 36 40]

Lower birth interval increases the risk of infant and child mortality in Bangladesh. Another prospective study in Bangladesh revealed similar results that preceding birth intervals significantly affect infant mortality.[41] It was further suggested that birth intervals sooner than 24 months and very short birth intervals, that is, less than

Table 2 Measures of goodness of fit for parametric frailty survival regression for under-5, infant and child mortality in BDHS 2017–2018

Under-5 mortality (0–59 months from birth)				
Model type	**Sample (N)**	**Loglikelihood**	**AIC**	**BIC**
Exponential	47 095	−22078.03	44 160.06	44 177.58
Weibull	47 095	−18919.83	37 845.65	37 871.93
Gompertz	47 095	−18297.42	36 600.85	36 627.13
Lognormal	47 095	−18684.81	37 375.61	37 401.89
Loglogistic	47 095	−18895.23	37 796.47	37 822.75
Infant mortality (0–11 months from birth)				
Model type	**Sample (N)**	**Loglikelihood**	**AIC**	**BIC**
Exponential	47 095	−16024.13	32 052.27	32 069.79
Weibull	47 095	−15178.94	30 363.89	30 390.17
Gompertz	47 095	−14223.34	28 452.68	28 478.96
Lognormal	47 095	−14984.56	29 975.13	30 001.41
Loglogistic	47 095	−15161.34	30 328.69	30 354.97
Child mortality (12–59 months from birth)				
Model type	**Sample (N)**	**Loglikelihood**	**AIC**	**BIC**
Exponential	42 611	−3666.04	7336.08	7353.40
Weibull	42 611	−3625.19	7256.37	7282.35
Gompertz	42 611	−3570.57	7147.14	7173.12
Lognormal	42 611	−3608.95	7223.90	7249.88
Loglogistic	42 611	−3624.74	7255.47	7281.45

AIC, Akaike information criteria; BDHS, Bangladesh Demographic and Health Survey; BIC, Bayesian Information Criteria.

Table 3 Absolute and percentage distribution of mothers and children by the number of children per mother and number of infant deaths per mother, respectively

Children per mother (N)	Infant deaths per mother (N)							Total mothers		Total children	Total deaths
	0	1	2	3	4	5	6	(N)	(Cum_%)	(Cum_%)	(Cum_%)
1	4329	75	–	–	–	–	–	4404	100.00	100.00	100.00
2	5507	270	11	–	–	–	–	5788	75.67	90.65	97.32
3	3292	557	29	2	–	–	–	3880	43.68	66.07	86.85
4	1514	504	70	8	2	–	–	2098	22.23	41.35	64.58
5	659	290	81	15	0	0	–	1045	10.63	23.53	40.33
6	290	143	48	10	2	1	0	494	4.85	12.44	22.5
7	120	75	35	13	4	1	1	249	2.12	6.15	12.39
8	38	27	10	4	2	1	0	82	0.74	2.45	4.82
9	15	14	2	2	2	1	0	36	0.29	1.06	2.24
10	3	1	3	1	0	0	0	8	0.09	0.37	0.91
11	1	4	1	0	0	0	0	6	0.05	0.20	0.55
12	0	0	0	1	0	0	0	1	0.02	0.06	0.33
13	0	0	0	0	0	0	1	1	0.01	0.03	0.22
Total mothers (N)	15768	1960	290	56	12	4	2	18092	100	100	100
Total mothers (Cum_%)	100.00	12.84	2.01	0.41	0.10	0.03	0.01	100	–	–	–
Children (Cum_%)	100.00	20.08	4.09	0.98	0.27	0.10	0.04	100	–	–	–
Deaths (Cum_%)	–	100.00	20.44	4.95	1.40	0.53	0.21	100	–	–	–

Cum_%, cumulative percentage in decreasing order; N, number.

18 months, lead to higher infant and child mortality.[42] Shorter preceding birth intervals may increase susceptibility to infections and poor maternal health.[42 43] Women from older cohorts were observed to have a higher HR for infant and child mortality. The results were consistent with the findings of previous studies.[19 44]

Table 4 Absolute and percentage distribution of mothers and children by the number of children per mother and number of child deaths per mother, respectively

Children per mother (N)	Child deaths per mother (N)				Total mothers		Total children	Total deaths
	0	1	2	3	(N)	(Cum_%)	(Cum_%)	(Cum_%)
1	4394	10	–	–	4404	100.00	100.00	100.00
2	5749	39	0	–	5788	75.67	90.65	98.19
3	3788	92	0	0	3880	43.68	66.07	91.16
4	1965	129	3	1	2098	22.23	41.35	74.58
5	939	100	5	1	1045	10.63	23.53	49.72
6	419	67	8	0	494	4.85	12.44	29.36
7	208	39	2	0	249	2.12	6.15	14.41
8	63	15	3	1	82	0.74	2.45	6.66
9	31	4	1	0	36	0.29	1.06	2.34
10	4	3	0	1	8	0.09	0.37	1.26
11	5	1	0	0	6	0.05	0.20	0.18
12	1	0	0	0	1	0.02	0.06	0.00
13	1	0	0	0	1	0.01	0.03	0.00
Total mothers (N)	17567	499	22	4	18092	100	100	100
Total mothers (Cum_%)	100.00	2.90	0.14	0.02	100	–	–	–
Children (Cum_%)	100.00	5.12	0.34	0.06	100	–	–	–
Deaths (Cum_%)	–	100.00	6.59	1.12	100	–	–	–

Cum_%, cumulative percentage in decreasing order.; N, number.

Table 5 HRs from Gompertz frailty regression models showing the multivariate association of infant and child deaths with child-specific, mother-specific and socioeconomic covariates, respectively, in Bangladesh

	Infant mortality (0–11 months)				Child mortality (12–59 months)			
	Model-I		Model-II		Model-I		Model-II	
Characteristics	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Birth cohort of index child								
2010–2018	Ref.		Ref.		Ref.		Ref.	
2005–2009	1.27*	(1.11 to 1.45)	1.05	(0.88 to 1.26)	1.26	(0.91 to 1.74)	1.38	(0.94 to 2.01)
2000–2004	1.39*	(1.22 to 1.58)	1.17	(0.98 to 1.40)	1.29	(0.93 to 1.79)	1.24	(0.84 to 1.84)
1995–1999	1.69*	(1.48 to 1.94)	1.33*	(1.10 to 1.61)	1.47*	(1.04 to 2.06)	1.35	(0.89 to 2.06)
1980–1994	2.61*	(2.28 to 3.00)	1.97*	(1.62 to 2.40)	3.78*	(2.75 to 5.19)	3.74*	(2.50 to 5.60)
Birth order of index child								
1–2	Ref.		Ref.		Ref.		Ref.	
3	0.82*	(0.72 to 0.93)	0.96	(0.83 to 1.10)	1.44*	(1.12 to 1.85)	1.20	(0.91 to 1.56)
4	0.85	(0.71 to 1.01)	0.98	(0.81 to 1.18)	1.70*	(1.23 to 2.37)	1.35	(0.95 to 1.92)
5 and more	0.95	(0.77 to 1.16)	1.04	(0.83 to 1.30)	1.92*	(1.30 to 2.84)	1.40	(0.92 to 2.13)
Gender of index child								
Female	Ref.		Ref.		Ref.		Ref.	
Male	1.26*	(1.17 to 1.36)	1.17*	(1.05 to 1.30)	0.84*	(0.71 to 0.99)	0.74*	(0.60 to 0.92)
Mother's age during birth of index child (in years)								
20–24	Ref.		Ref.		Ref.		Ref.	
Less than 20	1.64*	(1.48 to 1.81)	1.38*	(1.20 to 1.60)	1.28*	(1.03 to 1.60)	1.14	(0.86 to 1.51)
25–29	1.01	(0.87 to 1.16)	1.17	(1.00 to 1.37)	0.79	(0.59 to 1.07)	0.91	(0.66 to 1.24)
30 and more	0.95	(0.78 to 1.17)	1.14	(0.91 to 1.42)	0.74	(0.48 to 1.12)	0.92	(0.59 to 1.43)
Mother's level of education								
Secondary or higher	Ref.		Ref.		Ref.		Ref.	
Upto primary	1.26*	(1.13 to 1.41)	1.17*	(1.00 to 1.37)	1.16	(0.89 to 1.49)	0.96	(0.70 to 1.32)
No formal schooling	1.37*	(1.20 to 1.55)	1.30*	(1.09 to 1.54)	1.70*	(1.29 to 2.24)	1.27	(0.91 to 1.78)
Religion of the household								
Islam	Ref.		Ref.		Ref.		Ref.	
Others	1.23*	(1.07 to 1.41)	1.32*	(1.09 to 1.59)	0.91	(0.65 to 1.28)	1.14	(0.77 to 1.69)
Place of residence								
City corporation	Ref.		Ref.		Ref.		Ref.	
Semiurban	0.83	(0.68 to 1.01)	0.82	(0.63 to 1.06)	0.72	(0.47 to 1.11)	1.03	(0.55 to 1.90)
Rural	0.84	(0.69 to 1.02)	0.74*	(0.57 to 0.95)	0.69	(0.46 to 1.05)	1.10	(0.60 to 1.99)
Household wealth quintile								

Continued

Table 5 Continued

Characteristics	Infant mortality (0–11 months)				Child mortality (12–59 months)			
	Model-I		Model-II		Model-I		Model-II	
	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Richest	Ref.		Ref.		Ref.		Ref.	
Richer	1.32*	(1.13 to 1.53)	1.27*	(1.03 to 1.57)	1.15	(0.81 to 1.65)	0.87	(0.55 to 1.38)
Middle	1.17	(1.00 to 1.38)	1.12	(0.89 to 1.40)	1.55*	(1.08 to 2.21)	1.43	(0.92 to 2.21)
Poorer	1.48*	(1.26 to 1.74)	1.32*	(1.05 to 1.66)	1.78*	(1.24 to 2.57)	1.55	(0.99 to 2.41)
Poorest	1.65*	(1.40 to 1.96)	1.47*	(1.17 to 1.85)	2.09*	(1.45 to 3.03)	1.93*	(1.23 to 3.03)
Country administrative division								
Khulna	Ref.		Ref.		Ref.		Ref.	
Mymensingh	1.37*	(1.13 to 1.65)	1.15	(0.89 to 1.49)	1.69*	(1.08 to 2.66)	1.64	(0.93 to 2.89)
Chattogram	1.07	(0.91 to 1.27)	0.88	(0.70 to 1.10)	2.10*	(1.42 to 3.11)	2.02*	(1.24 to 3.32)
Rangpur	1.09	(0.92 to 1.30)	0.99	(0.78 to 1.26)	1.10	(0.71 to 1.71)	1.06	(0.61 to 1.85)
Rajshahi	1.25*	(1.05 to 1.48)	1.10	(0.87 to 1.40)	1.70*	(1.13 to 2.57)	1.78*	(1.06 to 2.99)
Dhaka	1.28*	(1.09 to 1.50)	1.04	(0.83 to 1.29)	1.64*	(1.10 to 2.44)	1.65	(0.99 to 2.73)
Barishal	1.10	(0.89 to 1.37)	1.09	(0.82 to 1.45)	2.32*	(1.48 to 3.65)	2.31*	(1.31 to 4.08)
Sylhet	1.55*	(1.27 to 1.90)	1.16	(0.89 to 1.50)	1.82*	(1.13 to 2.92)	1.53	(0.84 to 2.77)
Survival status of previous sibling at the time of conception of index child								
Alive			Ref.				Ref.	
Dead	–	–	1.86*	(1.59 to 2.17)	–	–	0.78	(0.54 to 1.11)
Birth interval preceding to index child (in months)								
28 and more months			Ref.				Ref.	
19–27 months	–	–	1.77*	(1.54 to 2.02)	–	–	1.82*	(1.41 to 2.34)
Less than 19 months	–	–	2.28*	(1.96 to 2.65)	–	–	2.24*	(1.66 to 3.02)
Gompertz regression shape parameter	–0.42*	(–0.44 to 0.40)	–0.39*	(–0.42 to 0.37)	–0.05*	(–0.05 to 0.04)	–0.05*	(–0.05 to 0.04)
Mother-level frailty effect	0.75*	(0.60 to 0.95)	0.33*	(0.17 to 0.65)	0.32*	(0.08 to 1.37)	0.54*	(0.14 to 2.03)
Likelihood ratio test	128.38*		11.73*		2.34*		3.04*	
No of mothers	18 092		13 705		17 332		13 019	
No of births	47 095		29 066		42 611		26 586	

Including the 'survival status of previous sibling at the time of conception of index child' and 'birth interval preceding to index child (in months)' variables in model-II reduces the number of observations as only second and higher-order births is analysed.
*P<0.05.
Ref, denotes reference category.

Women with higher birth orders had higher likelihood odds of child mortality. The results were consistent with previous studies[45 46] and can be explained using the Resource Depletion Hypothesis, which states that emotional and material resources become scarce with the increasing birth order and may lead to a higher risk of mortality among children and infants.[47] Younger mothers had a higher likelihood of infant and child mortality. The finding was parallel with previous literature that argued that children's risk of death is higher among young mothers. The reason may be the immature behaviour of young mothers and less stability to handle babies with complexities during childbirth.[48 49] Additionally, the likelihood of child complexities and low birth weight, small for gestational age infants and preterm deliveries are common among young mothers, which poses a significant risk of infant and child mortality.[50 51]

Mothers with no formal education had a higher HR for infant and child mortality. Women with no formal education may not have better socioeconomic status and minimal childcare knowledge. Uneducated women may not be aware of child-related illnesses and the preventive care required for their mitigation.[21 52] Moreover, women with no formal education had less autonomy, lesser decision making power and lower empowerment which may be a plausible reason for adverse outcomes for child's health and hence lead to higher child mortality.[53 54] Previous studies confirmed that although infant and child mortality has declined over time in Bangladesh, socioeconomic inequality in infant and child mortality persists.[55] The explanation can be given in terms of five proximate determinants influenced by socioeconomic characteristics. The set of five proximate determinants included environmental contamination, maternal factors, personal illness control, nutrient deficiency and injury.[55] Therefore, the previous studies were consistent with the present study's findings, which revealed that children from the poorest wealth quintile households had a higher HR for infant and child mortality. However, this study also found that infant mortality was higher in both richer and poorest households.

The current work, backed by the methodological advantage of the Gompertz shared frailty model, has provided substantial evidence of early life mortality clustering in Bangladesh. The model helped capture the correlation between mortality risks among siblings and the role of unobserved heterogeneity at the family level while considering the censored observations, which were lacking in earlier research. Although the effect of scaring and unobserved heterogeneity was more substantial among infant mortality, a subsequent higher amount of child death clustering in some families had paved the way for further research considering these two age brackets (ie, 0–11 months and 12–59 months) separately while observing the determinants in under-5 mortality. Besides these advantages, this study has a few limitations too. First, the study results do not provide any causal inference due to the cross-sectional nature of the data. Second, the entire birth history of mothers might have introduced recall bias in the results, especially about the earlier births. Third, in accordance to past research, community-level effect should also be considered while studying infant and child mortality.[24] However, the present setting of shared frailty model does not allow us to include both mother and community-level frailty effect in the same model.

CONCLUSION

The study found a significant scarring effect on infant mortality (0–11 months) in Bangladesh. However, the scarring effect was not significant in the case of child mortality (12–59 months). This study suggests that preceding birth interval, mother's age at first birth and mother's education are essential factors that can help reduce the phenomenon of death clustering in infants and children. Proper counselling is recommended among mothers who lost their previous child. As this may help her recover from the post-traumatic stress, and she can focus on her health and the health of her upcoming child.[39] Further, sensitisation is required in women irrespective of their socioeconomic strata as infant mortality is concentrated in both rich and poor families.

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Ethics approval This study involves human participants and was approved by Procedures and questionnaires for standard DHS surveys have been reviewed and approved by ICF Institutional Review Board (IRB). Additionally, country-specific DHS survey protocols are reviewed by the ICF IRB and typically by an IRB in the host country. ICF IRB ensures that the survey complies with the US Department of Health and Human Services regulations for the protection of human subjects (45 CFR 46), while the host country IRB ensures that the survey complies with the laws and norms of the nation. Participants gave informed consent to participate in the study before taking part.

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