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Dynamics of birth intervals in Bangladesh among reproductive-aged women: Frailty model approaches

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Corresponding Author:	Md. Moyazzem Hossain Jahangirnagar University Savar, Dhaka BANGLADESH
Keywords:	Bangladesh; Birth Interval; Frailty Models; Weibull gamma shared frailty model
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I am enclosing herewith a manuscript entitled "***Dynamics of birth intervals in Bangladesh among reproductive-aged women: Frailty model approaches***" submitted to your journal. Successive birth interval is a determinant of fertility rate and population growth - and has overarching implications for a country's development and standard of living. This study sought to identify the demographic and socio-economic determinants associated with successive short birth intervals among Bangladeshi married women. The authors also evaluate the fitness of various frailty and shared models.

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Sincerely Yours,
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Dynamics of birth intervals in Bangladesh among reproductive-aged women: Frailty model approaches

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Abstract

Background: Successive birth interval is a determinant of fertility rate and population growth - has overarching implications for a country's development and standard of living. This study sought to identify the demographic and socio-economic determinants associated with successive short birth intervals among Bangladeshi married women. The authors also evaluate the fitness of various frailty and shared models.

Methods and Materials: The findings are based on a secondary dataset extracted from a country-representative Bangladesh Demographic and Health Survey (BDHS) 2017-18 consisting of 27,134 women. Descriptive statistics, chi-square and Exponential, Weibull, Log-Logistic, Log-normal, and Gompertz models included in both the gamma frailty and gamma shared frailty models are used in this study.

Results: Women who married between ages 16-21 years had intervals shortened by -0.109 units (95% CI: -0.141 to -0.077) and those aged 22 year or older by -0.261 units (95% CI: -0.349 to -0.174) compared to those married at or before age 15 year. Moreover, the educational attainment of the respondents inversely impacted intervals; notably, individuals with higher education had intervals reduced by -0.178 units (95% CI: -0.241 to -0.116) compared to their uneducated women. Findings revealed that the key determinants affecting successive short birth intervals were identified as age at marriage, age at first birth, education level, contraceptive use, employment status, and wealth index. Additionally, enhancements in a woman's socio-economic standing and educational attainment tend to correlate with decreased fertility. Findings suggest that the Weibull Gamma Shared Frailty Model is better fitted model among the models considered in this study.

Conclusion: Female participation in the education programs needs to be increased because it consequently reduces the risk of shorter birth interval. The study also suggests that early marriage and early pregnancies should be reduced to improve the maternal and child health of the country as a whole. This research's findings offer essential insights for policy deliberations, emphasizing the need for strategies to promote sustainable increases in successive birth intervals, ensuring improved public health and developmental outcomes in Bangladesh.

Keywords: Bangladesh; Birth Interval; Frailty Models; Weibull gamma shared frailty model

Introduction

Population dynamics, particularly reproductive patterns, hold great significance in shaping the socio-economic and health trajectory of a country [1]. One of the essential metrics within this sphere is the successive birth interval - the period between two consecutive childbirths. This metric is not merely a demographic indicator; it bears direct consequences on maternal and child health outcomes [2], socio-economic wellbeing, and offers insights into prevailing cultural and familial practices [3]. In the global context, the dynamics of population growth and reproductive patterns are pivotal in shaping socio-economic landscapes, influencing national health strategies, and determining resource allocations [4]. This becomes especially salient in countries like Bangladesh, characterized by its unique socio-cultural fabric and undergoing transformative changes [5,6]. In many developing nations, including Bangladesh, understanding birth interval dynamics becomes critical given the complex interplay between socio-cultural norms, economic conditions, and health systems. For Bangladeshi women of reproductive age, short birth intervals can heighten risks to both mother and child, exacerbating vulnerabilities related to maternal morbidity, neonatal mortality, and suboptimal child health outcomes [7,8]. Bangladesh, with its multifaceted socio-cultural landscape, offers a poignant context to explore these successive birth intervals. As the nation grapples with rapid urbanization, evolving socioeconomic structures, and a growing population, understanding the nuances of birth intervals among Bangladeshi married women becomes paramount [5].

One pivotal aspect that has drawn attention in recent years is the identification of determinants or risk factors associated with short birth intervals. Several determinants, ranging from biological to sociocultural, shape the duration of birth intervals. Factors such as maternal age, educational attainment, economic conditions, exposure to family planning information, and cultural norms have been shown to significantly influence reproductive decisions [9,10] Furthermore, in societies with pronounced patriarchal systems, like Bangladesh, spousal and familial influences might considerably affect a woman's reproductive choices [11,12]. Furthermore, with Bangladesh's unique demographic landscape, where factors such as a dense population, varying literacy rates among women, and regional disparities in healthcare access come into play, the determinants of birth intervals might manifest differently than in other contexts [13]. At the macroscopic level, birth intervals can impact national fertility rates, dictating the pace of population growth and influencing broader policies related to health, education, and social welfare [14,15]. Consequently, a comprehensive understanding of the determinants of successive birth intervals in the Bangladeshi context can furnish policymakers, researchers, and healthcare professionals with the insights needed to devise impactful interventions and strategies.

The application of frailty model approaches offers a robust statistical framework to delve deeper into different determinants, accounting for unobserved heterogeneity and enabling a nuanced understanding of the factors driving short birth intervals among reproductive-aged women in Bangladesh [16]. Recent research in reproductive health underscores the importance of these models. For instance, studies on birth intervals in developing nations, including the effects of maternal education on childbearing, have embraced frailty models to navigate the unobserved heterogeneity [17,18]. Shared frailty models, on the other hand, have been instrumental in dissecting birth spacing and child mortality by accounting for intra-family correlations [19]. This study aims to comprehensively investigate the determinants influencing birth intervals among married women aged 15-49 years in Bangladesh. Specifically, the authors employ frailty and shared frailty models to analyse the impact of different factors including age at marriage and first birth, education level, contraceptive use, employment status, and wealth index on birth interval dynamics. By applying these statistical models within the unique socio-cultural context of Bangladesh, the findings of this study provide a deeper and more nuanced understanding of birth interval patterns. The insights gained from this study, enriched by the frailty models, are intended to offer valuable contributions not only to the academic community but also to inform and improve the nation's health policy programs.

Methods and Materials

Data Source

Secondary data from the 2017-18 BDHS were used for this Study. The data set was retrieved from the website https://dhsprogram.com after the measure DHS data for Bangladesh had granted permission for use. A data extraction technique was used to extract variables from the BDHS 2017-8 individual women's data. The study comprised 27,134 respondents in total. All sampling techniques are detailed in the annual BDHS reports. The data is publicly accessible at (https://www.dhsprogram.com). However, we implement the following diagram (Fig. 1) to demonstrate the sampling techniques and process of data extraction.

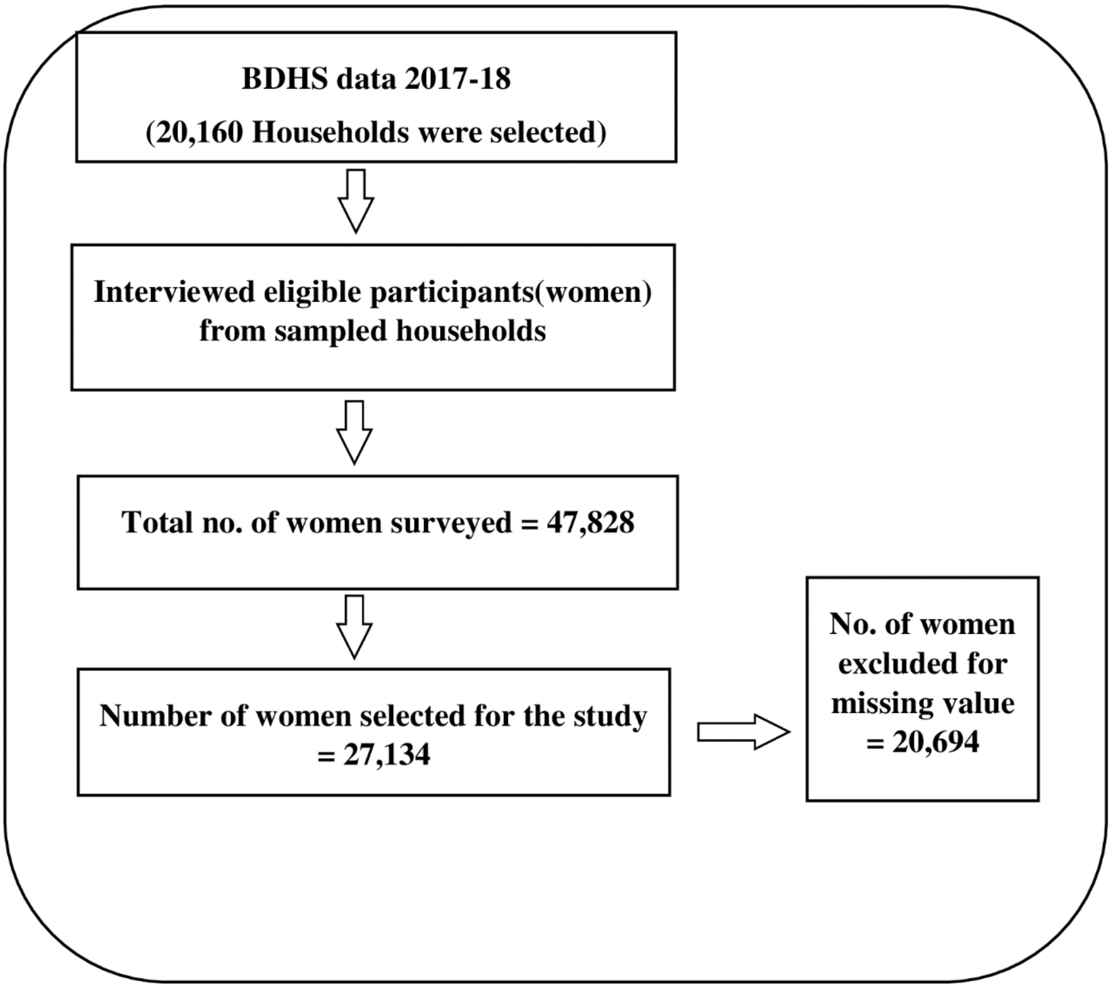


Fig. 1: Schematic representation of the sampling procedures in the study

Study Variables

The dependent variable of this study is whether or not birth had occurred during the interval where the successive birth interval was defined as the duration of months between the birth of the index child and the subsequent live birth. The event was defined as the occurrence of live birth after the index child (coded as 1), while women who did not give birth until the end of the follow-up period were considered as censored (coded as 0). To determine the impact of demographic and socio-economic determinants on the successive birth interval of married women in Bangladesh, the following independent variables are considered: respondent’s current age, age at marriage, age at first birth, body mass index (BMI), use of contraception, knowledge of ovulatory cycle, division, place of residence, religion, respondent’s education level, respondent’s working status, husband’s age, husband’s education level, husband’s occupation, husband’s desire for children, wealth index, and media exposure.

Data Management and Statistical Analysis

In this study, the authors utilized weighted data to account for the sampling design, ensuring accurate statistical estimates derived from the Bangladesh Demographic and Health Survey (BDHS). Given the inherent nature of the BDHS data, which violates the independence of observations and equal variance assumptions, our analytical process recognized potential correlations among women within the same cluster. The authors employed the STATA version 15 software for descriptive and summary statistics. Time-to-event data led us to use survival analysis techniques, including the Kaplan-Meier method and the log-rank test, for contrasting survival curves across various explanatory variables. The Cox proportional hazard model pinpointed predictors of birth interval. When the Proportional Hazard assumption did not hold, as validated by the global Schoenfeld residual test, the authors turned to parametric survival models. The hierarchical data structure from the BDHS was assessed for clustering using the frailty model, revealing significant unobserved heterogeneity or shared frailty. Consequently, the authors modelled shared frailty model with baseline distributions (Weibull, Gompertz, Exponential, loglogistic, and lognormal) and frailty distributions (gamma). By taking region as a random effect using shared frailty models, with the Gompertz gamma shared frailty model emerging as the best fit based on its log-likelihood, AIC and BIC values.

Ethical Approval

Ethical approval was not required as the survey was approved by the local Ethics Committee of Bangladesh and the Ethics Committee of the ICF Macro at Calverton, New York, USA. Permission for data access was obtained from major demographic and health survey through an online request from https://www.dhsprogram.com. The data used for this study were publicly available with no personal identifier.

Results

Background Characteristics

It is observed that among 27,134 married women, 19.8 percent of them gave birth during the last three years and 80.2 percent of married women didn’t give any birth during the last three years. Table 1 illuminates distinct patterns concerning recent birth events when viewed against various demographic and socio-economic categorizations. Most strikingly, the younger age group (≤18) exhibited an overwhelming birth occurrence of 97.6%, whereas in the 19-25 age bracket it was 74.1%, and only 15.5% for those aged 26+ (Log rank test chi-square: 5718.955, p-value <0.001). This demonstrates a sharp decline in birth events as age increases. Marital age also had profound implications: those who married at age ≤15 had a birth occurrence of 16.1% compared to those who married after 22, at 32.3% (Log rank test chi-square: 220.143, p-value <0.001). Similar patterns emerged concerning age at first birth. Those who had their first birth at age ≤15 reported an event of 16.2% as opposed to 24% for those at age 22+ (Log rank test chi-square: 55.034, p-value <0.001). Body Mass Index (BMI) influenced birth occurrences as well, with thin respondents indicating a 25.5% occurrence contrasting with obese respondents at 15.6% (Log rank test chi-square: 410.294, p-value <0.001). Educational attainments were also influential: those without any education had a birth occurrence of just 9.7%, while for those with higher education, it rose significantly to 30.9% (Log rank test chi-square: 373.898, p-value <0.001). Furthermore, distinctions based on residence type showed that urban women had birth occurrences at 19.4% versus rural women at 20% (Log rank test chi-square: 26.703, p-value <0.001). Across divisions, Sylhet recorded the highest occurrence at 26.4% while Rajshahi was at the lowest end with 14.8% (Log rank test chi-square: 917.908, p-value <0.001). Religious distinctions unveiled that 20.1% of Muslim respondents reported a birth event compared to 16% of others (Log rank test chi-square: 26.127, p-value <0.001). Notably, contraceptive usage insights revealed that 43.2% of those not using any method had a birth event compared to a mere 1.9% among those classified under 'others' (Log rank test chi-square: 1677.974, p-value <0.001). Moreover, work status, media exposure, husband’s age and education, the combined wealth index, and desire for children further demonstrated substantial variations in birth events, all displaying statistically significant p-values.

Table 1: Distribution of the variables and their association with successive birth interval by using Log-Rank test

Variable			Event (Birth in last 3 years)		Log rank test chi-square	p-value
Name	**Category**	**Total**	**Yes (%)**	**No (%)**		
Respondent's current age	< =18	41 (0.15%)	40 (97.6%)	1 (2.4%)	5718.955	<0.001
	19-25	1925 (7.09%)	1426 (74.1%)	499 (25.9%)		
	26+	25168 (92.75%)	3910 (15.5%)	21258 (84.5%)		
Age at Marriage	< = 15	13997 (51.58%)	2248 (16.1%)	11749 (83.9%)	220.143	<0.001
	16-21	12543 (46.23%)	2936 (23.4%)	9607 (76.6%)		
	22+	594 (2.19%)	192 (32.3%)	402 (67.7%)		

Variable		Event (Birth in last 3 years)			Log rank test chi-square	p-value
Name	**Category**	**Total**	**Yes (%)**	**No (%)**		
Age at first birth	< = 15	7155 (26.37%)	1161 (16.2%)	5994 (83.8%)	55.034	<0.001
	16-21	17831 (65.71%)	3700 (20.8%)	14131 (79.2%)		
	22+	2148 (7.92%)	515 (24%)	1633 (76%)		
Body Mass Index	Thin	3209 (11.83%)	818 (25.5%)	2391 (74.5%)	410.294	<0.001
	Normal	14933 (55.03%)	3239 (21.7%)	11694 (78.3%)		
	Overweight	7083 (26.10%)	1021 (14.4%)	6062 (85.6%)		
	Obesity	1909 (7.04%)	298 (15.6%)	1611 (84.4%)		
Respondent's education level	No education	7305 (26.92%)	707 (9.7%)	6598 (90.3%)	373.898	<0.001
	Primary	10899 (40.17%)	2027 (18.6%)	8872 (81.4%)		
	Secondary	7556 (27.85%)	2217 (29.3%)	5339 (70.7%)		
	Higher	1374 (5.06%)	425 (30.9%)	949 (69.1%)		
Type of place of residence	Urban	8544 (31.49%)	1655 (19.4%)	6889 (80.6%)	26.703	<0.001
	Rural	18590 (68.51%)	3721 (20%)	14869 (80%)		
Division	Barisal	3044 (11.22%)	542 (17.8%)	2502 (82.2%)	917.908	<0.001
	Chittagong	4367 (16.09%)	989 (22.6%)	3378 (77.4%)		
	Dhaka	3587 (13.22%)	708 (19.7%)	2879 (80.3%)		
	Khulna	2870 (10.58%)	430 (15%)	2440 (85%)		
	Mymensingh	3165 (11.66%)	690 (19.8%)	2475 (78.2%)		
	Rajshahi	3031 (11.17%)	450 (14.8%)	2581 (85.2%)		
	Rangpur	3335 (12.29%)	580 (17.4%)	2755 (82.6%)		
	Sylhet	3735 (13.77%)	987 (26.4%)	2748 (73.6%)		
Religion	Islam	24977 (92.05%)	5030 (20.1%)	19947 (79.9%)	26.127	<0.001
	Others	2157 (7.95%)	346 (16%)	1811 (84%)		
Current Contraceptive Use	Do not Use	3632 (13.39%)	1570 (43.2%)	2062 (56.8%)	1677.974	<0.001
	Traditional Method	3724 (13.72%)	383 (10.3%)	3341 (89.7%)		
	Modern Method	14510 (53.48%)	3324 (22.9%)	11186 (77.1%)		
	Others	5268 (19.41%)	99 (1.9%)	5169 (98.1%)		
Knowledge of Ovulatory Cycle	During Period	476 (1.75%)	104 (21.8%)	372 (78.2%)	11.584	<0.001
	Before	13263 (48.88%)	2653 (20%)	10610 (80.0%)		
	After	9166 (33.78%)	1773 (19.3%)	7393 (80.7%)		
	Others	4229 (15.59%)	846 (20%)	3383 (80.0%)		
Respondent's Working Status	No	12197 (44.95%)	2909 (23.9%)	9288 (76.1%)	179.268	<0.001
	Yes	14937 (55.05%)	2467 (16.5%)	12470 (83.5%)		
Media Exposure	No	15147 (55.82%)	3209 (21.2%)	11938 (78.8%)	179.900	<0.001
	Yes	11987 (44.18%)	2167 (18.1%)	9820 (81.9%)		
Husband's Age	<=30	1721 (6.34%)	1160 (67.4%)	561 (32.6%)	4806.076	<0.001
	30-40	7912 (29.16%)	2887 (36.5%)	5025 (63.5%)		
	40+	17501 (64.50%)	1329 (7.6%)	16172 (92.4%)		
Husband's Education	No education	8839 (32.58%)	1258 (14.2%)	7581 (85.8%)	103.094	<0.001
	Primary	9403 (34.65%)	2002 (21.3%)	7401 (78.7%)		
	Secondary	6260 (23.07%)	1486 (23.7%)	4774 (76.3%)		
	Higher	2632 (9.70%)	630 (23.9%)	2002 (76.1%)		
Husband's Occupation	Job	4152 (15.30%)	920 (22.2%)	3232 (77.8%)	.860	0.651
	Business	5088 (18.75%)	1060 (20.8%)	4028 (79.2%)		
	Others	17894 (65.95%)	3396 (19%)	14498 (81.0%)		
Wealth Index (Combined)	Poorest	6322 (23.30%)	1542 (24.4%)	4780 (75.6%)	294.186	<0.001
	Poorer	5918 (21.81%)	1177 (19.9%)	4741 (80.1%)		
	Middle	5333 (19.65%)	898 (16.8%)	4435 (83.2%)		
	Richer	5131 (18.91%)	949 (18.5%)	4182 (81.5%)		

Variable			Event (Birth in last 3 years)		Log rank test chi-square	p-value
Name	Category	Total	Yes (%)	No (%)		
	Richest	4430 (16.33%)	810 (18.3%)	3620 (81.7%)		
Husband Desire for Children	Both wanted same	17606 (64.89%)	3728 (21.2%)	13878 (78.8%)	81.880	<0.001
	Husband wanted more	4124 (15.20%)	845 (20.5%)	3279 (79.5%)		
	Husband wanted less	1534 (5.65%)	327 (21.3%)	1207 (78.7%)		
	Others	3870 (14.26%)	476 (12.3%)	3394 (87.7%)		

Checking Proportional Hazard (PH) Assumption

To check if the proportional hazard assumptions (PH Assumption) are violated or not, we use Schoenfeld Residual Test and Kaplan Meier Survival Curves. The following segments 2 and 3 shows the outputs of Schoenfeld Residual Test and Kaplan Meier Survival Curves respectively.

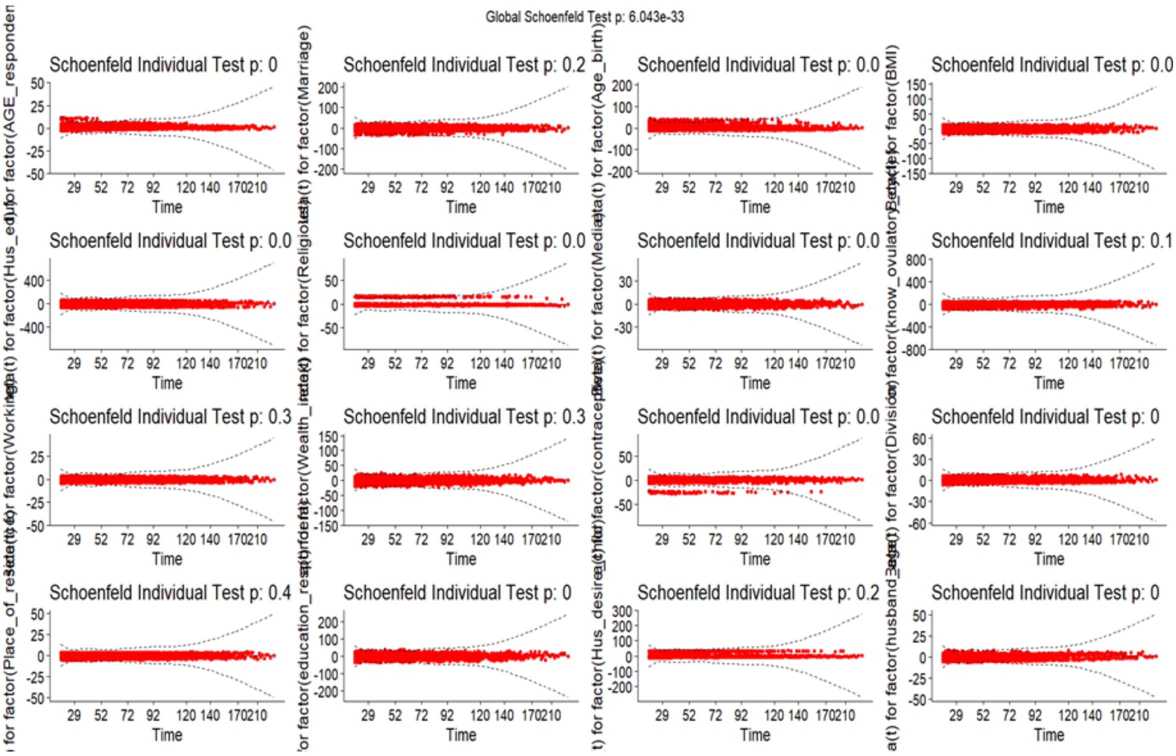
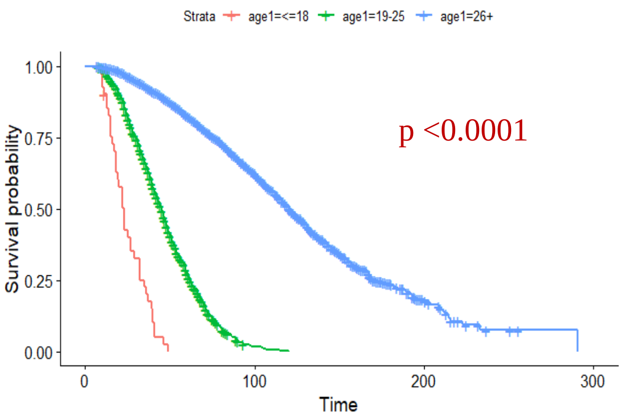
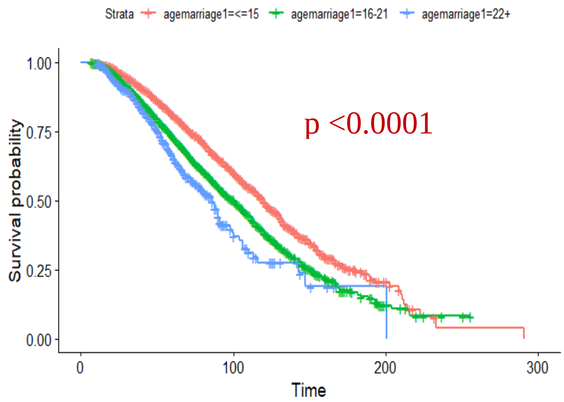


Fig. 2: Schoenfeld residual test

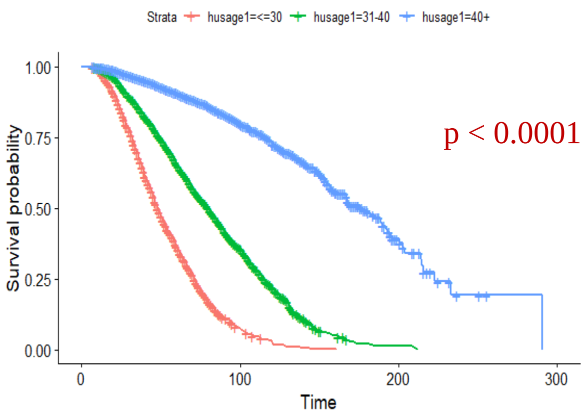
Fig. 2 illustrates the Schoenfeld individual test plots for each variable in the study. The solid line denotes a smoothing spline fit, flanked by dashed lines representing its bounds. A horizontal trajectory would indicate proportional hazards. However, noticeable departures from this trajectory signify non-proportional hazards. Our graphical evaluation doesn't exhibit a consistent trend with time, suggesting a violation of the proportional hazard (PH) assumption. This assertion is further substantiated by the p-values below the typical significance threshold of 0.05, which points to the non-compliance of the PH assumption. This necessitates exploration of alternative modelling strategies or a deeper dive into the nature of this violation. The authors also used Kaplan Meier survival plots to check if proportional hazard assumption holds or not. The Kaplan Meier survival plots are given below:



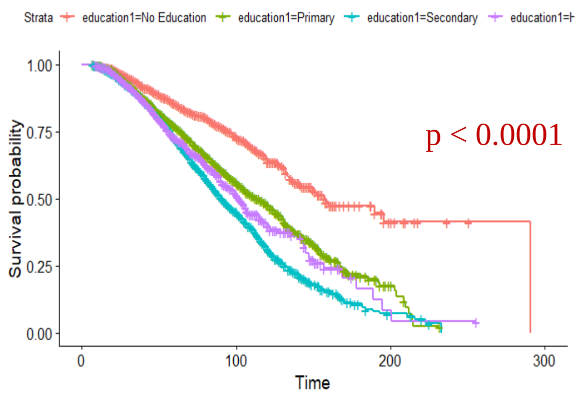
KM Survival Plot of the age of respondent



KM Survival Plot of age of at marriage



KM Survival Plot of Husband's Age



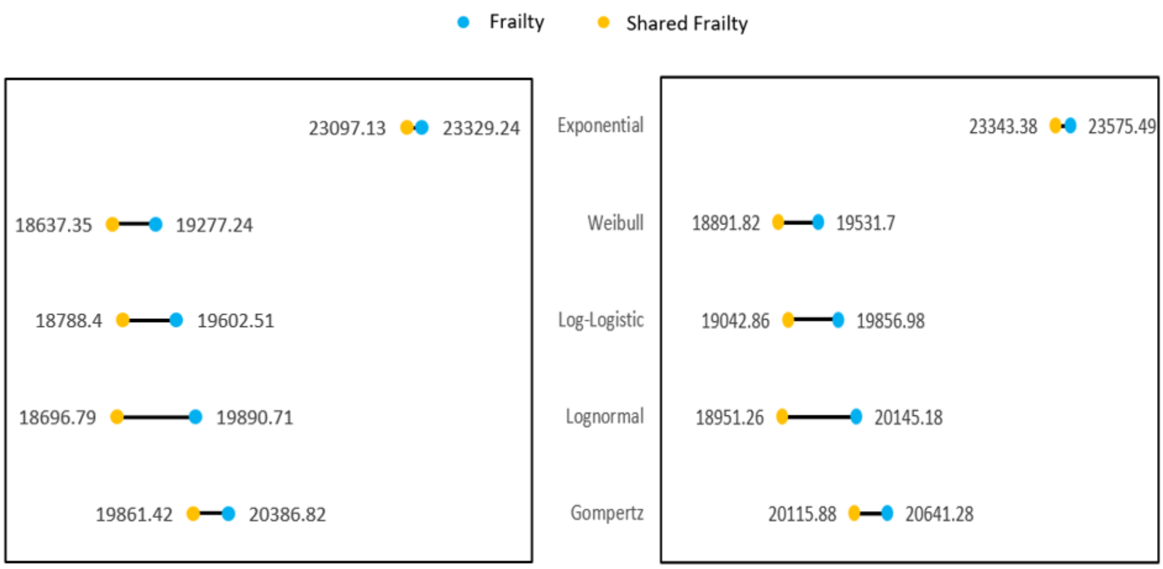
KM Survival Plot of Respondent's Education

Fig. 3: Kaplan Meier Survival plots of the selected variables

Fig. 3 represents Kaplan-Meier survival plots for categorical variables, with associated p-values indicating statistical significance. Clear distinctions in survival curves among variable categories suggest significant survival differences among groups. Several variables, including respondent's age, age at marriage and first birth, BMI, contraception use, ovulatory cycle knowledge, education, work status, religion, media exposure, residence, division, husband's age, husband's education, wealth index, and husband's childbearing preferences, all demonstrate significant differences in survival among their respective categories (Fig. S1) However, the variable 'husband's occupation' does not display a notable variance in survival curves between its groups, indicating no significant survival difference among its categories.

Comparison of Frailty and Shared Frailty Models

The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) for the frailty and shared frailty models are obtained. Comparison of frailty and shared frailty models by using AIC and BIC are presented in Fig. 4. The authors fitted Exponential, Weibull, Log-Logistic, Log-normal, Gompertz models both as gamma frailty and gamma shared frailty models. It is known that the model with the lowest AIC or BIC value is considered to be the best among the candidate models.



AIC for Frailty and Shared Frailty model BIC for Frailty and Shared Frailty model

Fig. 4: Comparison of frailty and shared frailty models

From the Fig. 4, it is observed that the Weibull gamma frailty model has the lowest AIC value (19277.24) as well as the lowest BIC value (19531.7) among all gamma frailty model used in this study. Similarly, Weibull gamma shared frailty model has the lowest AIC value (18637.35) as well as the lowest BIC value (18891.82) among all gamma shared frailty model used in this study. Thus, it can be said that the Weibull gamma shared frailty model performs better than all other gamma shared frailty models fitted in this study to estimate successive birth interval of married women in Bangladesh. These findings suggest that the Weibull Gamma Shared Frailty model performs better than the Weibull Gamma Frailty models in terms of estimating the successive birth interval of married women in Bangladesh.

Weibull Gamma Shared Frailty Model

In the Weibull gamma shared frailty model analysis, age at marriage significantly influenced intervals. Specifically, women who married between ages 16-21 years had intervals shortened by -0.109 units (95% CI: -0.141 to -0.077) and those aged 22 year or older by -0.261 units (95% CI: -0.349 to -0.174) compared to those married at or before age 15 year. The current age of respondents also had a profound effect; women aged 26 year and above exhibited a lengthened interval by 1.236 units (95% CI: 1.091 to 1.381) compared to the younger group aged 18 year or less. In the case of BMI, compared to thin women, those categorized as overweight had the most pronounced increase in intervals by 0.236 units (95% CI: 0.192 to 0.280). Those from religious affiliations other than Islam demonstrated longer intervals by 0.173 units (95% CI: 0.123 to 0.223). The influence of media exposure was also evident, with exposed women having intervals extended by 0.037 units (95% CI: 0.006 to 0.069). With husbands' age ascending, intervals expanded, peaking at 0.590 units (95% CI: 0.543 to 0.636) for those aged 40+ year. Educational attainment of the respondent inversely impacted intervals; notably, individuals with higher education had intervals reduced by -0.178 units (95% CI: -0.241 to -0.116) compared to their uneducated women. Among contraceptive users, traditional method users experienced a notable decrease in intervals by -0.230 units, though the provided CI seems to be potentially miswritten. The working status of respondents also mattered: working individuals had intervals decreased by -0.074 units (95% CI: -1.08 to -0.001). Economic considerations were evident in the wealth index, with the richest category displaying an interval expansion by 0.295 units (95% CI: 0.240 to 0.349) relative to the poorest. Regarding couples' fertility preferences, if the husband desired more children, intervals shortened by -0.097 units (95% CI: -0.130 to -0.063) in relation to mutual desires. The shared frailty component, represented by θ, was documented at 0.152 with a standard error of 0.075. These values indicate that there is regional heterogeneity or regional effect for the determinants of birth interval of married women of Bangladesh.

Table 3: Weibull Gamma Shared Frailty Model

Variable	Category	$\widehat{\beta}$	P-value	95% CI Lower Bound	95% CI Upper Bound
Age at marriage	< =15 (RC)				
	16-21	-0.109	<0.001	-0.141	-0.077
	22+	-0.261	<0.001	-0.349	-0.174
Respondent's current age	< = 18 (RC)				
	19-25	0.719	<0.001	0.576	0.861
	26+	1.236	<0.001	1.091	1.381
Age at first birth	< = 15 (RC)				
	16-21	-0.088	<0.001	-0.126	-0.051
	22+	-0.258	<0.001	-0.322	-0.195
Body Mass Index	Thin (RC)				
	Normal	0.090	<0.001	0.055	0.125
	Overweight	0.236	<0.001	0.192	0.280
	Obesity	0.147	<0.001	0.083	0.210
Religion	Islam (RC)				
	Others	0.173	<0.001	0.123	0.223
Media Exposure	No (RC)				
	Yes	0.037	0.020	0.006	0.069
Husband's Age	<=30 (RC)				
	30-40	0.110	<0.001	0.073	0.147
	40+	0.590	<0.001	0.543	0.636
Respondent's education level	No education (RC)				
	Primary	-0.056	0.005	-0.096	-0.017
	Secondary	-0.096	<0.001	-0.138	-0.055
	Higher	-0.178	<0.001	-0.241	-0.116
Type of place of residence	Urban (RC)				
	Rural	0.049	0.135	-0.015	0.114
Current Contraceptive Use	Do not Use (RC)				
	Traditional Method	-0.230	<0.001	0.178	0.282
	Modern Method	--0.085	<0.001	0.057	0.113
	Others	0.786	<0.001	0.692	0.879
Respondent's Working Status	No (RC)				
	Yes	-0.074	<0.001	-1.08	-0.001
Wealth Index (Combined)	Poorest (RC)				
	Poorer	0.093	<0.001	0.058	0.129

Variable	Category	$\widehat{\beta}$	P-value	95% CI Lower Bound	95% CI Upper Bound
	Middle	0.183	<0.001	0.142	0.225
	Richer	0.186	<0.001	0.142	0.230
	Richest	0.295	<0.001	0.240	0.349
Husband Desire for Children	Both wanted same (RC)				
	Husband wanted more	-0.097	<0.001	-0.130	-0.063
	Husband wanted less	-0.004	0.862	-0.055	0.046
	Others	-0.023	0.304	-0.067	0.021
Shared Frailty	θ	0.152			
Std. Error	SE(θ)	0.075			

Note: $\widehat{\beta}$: Coefficient; CI: Confidence interval; RC: Reference Category; SE: Standard Error.

Discussion

Successive birth interval, also referred to as birth spacing, plays an integral role in deciphering fertility patterns, maternal and child health, and broader population dynamics [20,21]. Historically significant in demography and reproductive health research, its importance is highlighted further in recent times given the evolving societal and health dynamics. In Bangladesh, a marked reduction in fertility rates over recent decades has been observed. Our study, in line with recent research, postulates this can be attributed to extended birth intervals among Bangladeshi women [22]. Bangladesh has experienced remarkable progress in reducing fertility rates over the past few decades. A significant factor contributing to this trend is the lengthening of birth intervals between successive pregnancies. As Bangladeshi married women tend to have longer birth interval, the fertility rate decreased significantly in the recent past. Our study confirms the critical role of successive birth intervals in shaping fertility patterns in the country. Longer birth intervals not only have implications for the health and well-being of both mothers and children but also influence demographic trends and population growth. In Bangladesh the analysis of successive birth intervals of married women is very crucial to understand the dynamics of fertility and maternal health. This study aimed to employing various parametric frailty and shared frailty models to investigate the determinants of successive birth intervals and for the purpose of analysis using BDHS 2017/2018 data. The study found that among the surveyed Bangladeshi married women, approximately 19.8 percent of them gave birth of one or more child during the past 3 years. On the other hand, approximately 80.2 percent married women of Bangladesh did not give birth of any child during the last 3 years.

The univariate results and the Log-rank test during bivariate analysis spotlights several determinants like respondent age, education level, and age at marriage as significant influencers [23]. Moreover, the Log-rank test confirms that region, place of residence, body mass index, use of contraception, working status, husband's age, husband's education, husband's desire for child, religion, division, knowledge of ovulatory cycle, wealth index and media exposure provide significant effects on successive birth interval and these significant covariates are only considered in the frailty and shared frailty models. Interestingly, echoing global trends, higher education in women corresponded with lengthier birth intervals [24]. A surprising revelation was that affluent women exhibited shorter birth intervals, possibly stemming from their confidence in managing child-rearing costs [25].

Then we compare the Gamma Frailty and Gamma Shared Frailty models by calculating Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). While the Gamma frailty models and shared frailty models were deployed, the Weibull Gamma Shared Frailty model emerged superior, highlighting regional disparities and confirming earlier studies indicating variations across Bangladeshi [26]. The Weibull gamma shared frailty model highlights significant determinants influencing birth intervals among Bangladeshi married women. Notably, age at marriage, respondent's current age, BMI, religious affiliations, media exposure, husbands' age, education level, contraceptive use, economic status, and couples' fertility preferences play crucial roles. For instance, women who marry after age 15 or are above 26 have adjusted intervals, with wealthier, educated, or media-exposed women showing varying effects. The shared frailty component suggests regional variations in these determinants.

Limitations

This study has a few limitations. Using the BDHS 2017-2018 data, which is cross-sectional, limits our ability to establish causality. Participants' self-reported answers may introduce recall biases. Additionally, chosen analytical model and broad wealth categorization could also influence the findings. These results might be specific to Bangladesh and not universally applicable.

Conclusion

The authors identified some important demographic and socio-economic determinants that may affect the successive birth interval of married women in Bangladesh of which some should be controlled. The study concludes that female participation in the education programs needs to be increased because it consequently reduces the risk of shorter birth interval. The study also suggests that early marriage and early pregnancies should be reduced to improve the maternal and child health of the country as a whole. Use of contraception should be increased among married couples. Therefore, government should provide high-impact health and nutrition interventions, arrange family and social awareness programs as well as health related programs for women so that they can take really good care of their health as well as the wellbeing of their child. Social awareness should be spread about that and warn people about the extensive impact of shorter birth interval and tell them how it affects the country in many ways. Necessary steps should be taken in order to lessen the risk factors and lengthen the birth interval as it may significantly impact the fertility rate and also can increase the population significantly.

Declarations

Consent to Publication

Not applicable.

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Conflict of Interest

The authors declare that they have no conflict of interest concerning the research, authorship, and publication of this article.

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Data Availability

This study is based on the secondary dataset, which can be accessed via the following link: http://dhsprogram.com/data/available-datasets.cfm.

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Fig. S1: Kaplan Meier Survival plots of different variables

Reference

1. Bongaarts J, Watkins SC. Social interactions and contemporary fertility transitions. Popul Dev Rev. 1996;22: 639.

2. Organisation WH. Report of a WHO Technical Consultation on Birth Spacing, World Health Organization, Geneva. 2007.

3. Cleland J, Bernstein S, Ezeh A, Faundes A, Glasier A, Innis J. Family planning: the unfinished agenda. Lancet (London, England). 2006;368: 1810–1827. doi:10.1016/S0140-6736(06)69480-4

4. Cleland J, Conde-Agudelo A, Peterson H, Ross J, Tsui A. Contraception and health. Lancet. 2012;380: 149–156. doi:10.1016/S0140-6736(12)60609-6

5. Mostafa Kamal SM. Decline in child marriage and changes in its effect on reproductive outcomes in Bangladesh. J Heal Popul Nutr. 2012;30: 317–330.

6. Hossain MA, Hossain MB. Understanding fertility behavior of the Forcibly Displaced Myanmar Nationals in Bangladesh: A qualitative study. PLoS One. 2023;18: 1–19. doi:10.1371/journal.pone.0285675

7. Miller JE, Trussell J, Pebley AR, Vaughan B, Miller JE, Pebley AR. Birth Spacing and Child Mortality in Bangladesh and the Philippines Published by : Springer on behalf of the Population Association of America Stable URL : https://www.jstor.org/stable/2061733 Birth Spacing and Child Mortality in Bangladesh and the Philip. 2020;29: 305–318.

8. Rutstein SO. 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. Int J Gynaecol Obstet Off organ Int Fed Gynaecol Obstet. 2005;89 Suppl 1: S7-24. doi:10.1016/j.ijgo.2004.11.012

9. Conde-Agudelo A, Rosas-Bermudez A, Castaño F, Norton MH. Effects of birth spacing on maternal, perinatal, infant, and child health: a systematic review of causal mechanisms. Stud Fam Plann. 2012;43: 93–114. doi:10.1111/j.1728-4465.2012.00308.x

10. Hewett PC, Mensch BS, Erulkar AS. Consistency in the reporting of sexual behaviour by adolescent girls in Kenya: a comparison of interviewing methods. Sex Transm Infect. 2004;80 Suppl 2: ii43-8. doi:10.1136/sti.2004.013250

11. Islam MM, Islam MK, Hasan MS, Hossain MB. Adolescent motherhood in Bangladesh: Trends and determinants. PLoS One. 2017;12: 1–14. doi:10.1371/journal.pone.0188294

12. Mason KO, Smith HL. Husbands' versus wives' fertility goals and use of contraception: the influence of gender context in five Asian countries. Demography. 2000;37: 299–311.

13. Abdus SobhanL M, Farooq HasanL M, Moyazzem Hossain M. Socio-Economic and Demographic Determinants of Birth Intervals among Married Women in Bangladesh. Jahangimagar Univ J Sci. 2018;41: 103–118.

14. Moultrie TA, Sayi TS, Timæus IM. Birth intervals, postponement, and fertility decline in Africa: a new type of transition? Popul Stud (NY). 2012;66: 241–258.

doi:10.1080/00324728.2012.701660

15. Westoff C, Bankole A. Mass Media and Reproductive Behavior in Pakistan, India, and Bangladesh. Media. 1999; 1–28.

16. Gutierrez RG. Parametric Frailty and Shared Frailty Survival Models. Stata J. 2002;2: 22–44. doi:10.1177/1536867X0200200102

17. Wiśniowski A, Smith PWF, Bijak J, Raymer J, Forster JJ. Bayesian Population Forecasting: Extending the Lee-Carter Method. Demography. 2015;52: 1035–1059. doi:10.1007/s13524-015-0389-y

18. Hougaard P. Frailty models for survival data. Lifetime Data Anal. 1995;1: 255–273. doi:10.1007/BF00985760

19. Kozuki N, Walker N. Exploring the association between short/long preceding birth intervals and child mortality: using reference birth interval children of the same mother as comparison. BMC Public Health. 2013;13 Suppl 3: S6. doi:10.1186/1471-2458-13-S3-S6

20. Nausheen S, Bhura M, Hackett K, Hussain I, Shaikh Z, Rizvi A, et al. Determinants of short birth intervals among married women: a cross-sectional study in Karachi, Pakistan. BMJ Open. 2021;11: e043786. doi:10.1136/bmjopen-2020-043786

21. Asif MF, Ishtiaq S, Abbasi NI, Tahir I, Abid G, Lassi ZS. The Interaction Effect of Birth Spacing and Maternal Healthcare Services on Child Mortality in Pakistan. Child (Basel, Switzerland). 2023;10. doi:10.3390/children10040710

22. Majumder N, Ram F. Explaining the role of proximate determinants on fertility decline among poor and non-poor in Asian countries. PLoS One. 2015;10: 1–27. doi:10.1371/journal.pone.0115441

23. Rabbi AMF, Karmaker SC, Mallick SA, Sharmin S. Determinants of Birth Spacing and Effect of Birth Spacing on Fertility in Bangladesh. Dhaka Univ J Sci. 2013;61: 105–110. doi:10.3329/dujs.v61i1.15105

24. Du KC, Mohosin AB, Amin A, Hasan MT. Influence of education on sexual and reproductive health service utilization for persons with disabilities in nationwide Bangladesh: an explanatory sequential mixed-methods study. Reprod Health. 2022;19: 1–15. doi:10.1186/s12978-022-01352-7

25. Colleran H, Jasienska G, Nenko I, Galbarczyk A, Mace R. Fertility decline and the changing dynamics of wealth, status and inequality. Proc R Soc B Biol Sci. 2015;282. doi:10.1098/rspb.2015.0287

26. Kamrul Islam M, Rabiul Haque M, Hema PS. Regional variations of contraceptive use in Bangladesh: A disaggregate analysis by place of residence. PLoS One. 2020;15: 1–18. doi:10.1371/journal.pone.0230143

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