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Disparities in adverse pregnancy outcomes for short and long birth intervals in Bangladesh: evidence from six Bangladesh Demographic and Health Surveys, 1996-2014

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ABSTRACT

Objective

To examine the effect of short (<36 months) and long (≥60 months) birth intervals on adverse pregnancy outcomes in Bangladesh.

Design, setting and participants

We analysed data from six Bangladesh Demographic and Health Surveys (1996-1997, 1999-2000, 2004, 2007, 2011 and 2014). We included all singleton non-first live births, most recently born to the mothers within five years preceding each survey (n=21,382). We defined birth interval according to previous literature which suggests that between 36 and 59 months is the most ideal interval. Bivariate and multivariable analyses were conducted to obtain the crude and adjusted odds ratio (aOR) respectively to assess the odds of first-day neonatal death, early neonatal death and small birth size for both short (<36 months) and long (≥60 months) spacing between births.

Main outcome measures

First-day neonatal death, early neonatal death and small birth size.

Results

In the multivariable analysis, compared to births spaced 36-59 months, infants with birth intervals of less than 36 months were associated with the increased odds of first-day neonatal death (aOR: 2.11, 95% CI: 1.17, 3.78) and early neonatal death (aOR: 1.58, 95% CI: 1.13, 2.22). Compared to births spaced 36-59 months, infants with birth interval of ≥60 months, were associated with the increased odds of first-day neonatal death (aOR: 2.02, 95% CI: 1.10, 3.73) and small birth size (aOR: 1.17, 95% CI: 1.02, 1.34). When there was a history of pregnancy loss, there was an increase in the odds of first-day and early neonatal death for both short and long birth intervals, although there was no association.

Conclusions

Birth intervals shorter than 36 months and longer than 59 months are associated with the increased risk of adverse perinatal outcomes. Care-providers, program managers and policymakers should focus on promoting the optimal birth interval between 36-59 months in postpartum family planning.

Key words: Pregnancy outcome, birth interval, first-day neonatal death, early neonatal death, small birth size, Bangladesh

Strengths and limitations of this study

- The main strength of this study is the use of a large sample from six nationally representative surveys of Bangladesh with a very high response (98%).
- We used the information of the most recent births within the 5 years preceding the surveys in order to minimise recall bias.
- Our study is the first in Bangladesh which analysed the effect of birth intervals and other risk factors for first-day neonatal mortality.
- Demographic and Health Survey data is cross-sectional, which reduces the ability to infer causation.
- Demographic and Health Survey data uses maternal perceptions of infant birth size as a proxy for birthweight which may be a limitation.

BACKGROUND

Adverse pregnancy outcomes such as stillbirth, early neonatal mortality and low birthweight are of considerable public health significance. Globally, perinatal mortality (stillbirth and early neonatal mortality) accounts for more than 6 million deaths every year. Of those, approximately 2 million newborns die in the early neonatal period.[1] The risk is greatest on the first day of life, approximately 1 million newborns die within the first 24 hours.[1] Further, low birthweight, occurs in more than 20 million newborns worldwide, which is a major indicator of perinatal mortality and contributes to up to 80% of neonatal mortality.[2] The greatest proportion of perinatal deaths and low birthweight (97-99%) occur in Low and Middle-Income Countries (LMIC).[3]

Several interventions have been suggested to address adverse pregnancy outcomes, such as pregnancy spacing.[4] Both short and long birth intervals have been reported to be associated with an increased risk of a number of adverse perinatal outcomes.[5 6] Current World Health Organization (WHO) guidelines recommend an interval of at least 24 months before attempting the next pregnancy after a live birth (i.e. birth-to-pregnancy interval) in order to reduce any adverse pregnancy outcomes.[7] Thus, the birth-to-birth interval should be at least 33 months by including nine months of pregnancy to the recommended 24 months.[8] In an analysis of Demographic and Health Survey data from 17 developing countries, Rutstein suggested that the optimal birth interval should be between 36 and 59 months as each birth interval less than 36 and more than 59 months showed a tendency towards neonatal mortality and morbidity.[9] The WHO highlighted the necessity of future research investigating the association between birth interval and adverse pregnancy outcomes.[7]

Bangladesh has high perinatal mortality (44 per 1000 pregnancies) and morbidity,[10] where birth spacing remains a problem.[11] Between the year 1993 and 2014, though the median birth interval increased by 49% (from 35 months to 52 months), approximately 30% of non-first births occurred within less than 36 months (7 months to 35 months) following the previous birth.[10] However, another 40% of non-first births occurred following a birth interval of more than 59 months.[10] Of the papers investigating birth interval in Bangladesh, most have focussed on the effect of short birth interval and have not considered a long birth interval as a risk of adverse perinatal outcome.[12 13] Given the changing demographics in Bangladesh and increase in proportion of longer birth intervals, our objective therefore was to examine whether the preceding birth interval (short or long) was independently associated with increased risk of adverse pregnancy outcomes including first-day neonatal mortality, early neonatal mortality and low birthweight using pooled data from the Bangladesh Demographic and Health Surveys.

METHODS

Data source

We used the Bangladesh Demographic and Health Survey (BDHS) data from the years; 1996-1997, 1999-2000, 2004, 2007, 2011 and 2014. BDHS is a nationally representative household survey carried out every three to four years under the authority of the National Institute of Population Research and Training of the Ministry of Health and Family Welfare. The survey employed a two-stage stratified cluster-sampling design with rural and urban samples to collect information from ever-married women aged 15-49 years and ever-married men 15-54 years about demographic and health status. Data were obtained from the website; www.measuredhs.com. The BDHS consists of three types of questionnaires: household, women, and men. Our analysis was limited to the information obtained from the women's and household questionnaires. We pooled the data files into a dataset and analysed the live births occurring during the five years preceding the surveys. In our analysis, we included the data from all singleton, non-first, most recent live-born children within the five years preceding the six BDHSs, 1996-1997, 1999-2000, 2004, 2007, 2011 and 2014.

Outcome variables

We conducted three analyses', with three different outcome variables-'first-day neonatal death', 'early neonatal death' and 'small birth size'. First-day deaths were defined as deaths during the first 24 hours after birth (day 0) among live-born children and early neonatal deaths were deaths between the age of 0 to 6 days among live-born children. These two outcome variables overlap, but conform to standard definitions. Estimates about birthweight are not collected by the BDHS. 'Mother's perception of the baby's birth size' is routinely used as a proxy indicator of birthweight. For our analysis, we defined low birthweight as infants whose mother's perception of size was either 'very small' or 'smaller than average'. Each of the outcome variables was considered dichotomous for this analysis as yes (1) or no (0).

Exposure variable

The main exposure variable used in our analysis was the length of the preceding birth interval as a measure of birth spacing. This was measured as the number of months between two successive live births.[9 14] We followed Rutstein's recommendation regarding optimal birth interval of 36-59 months for our analysis.[9] We categorised preceding birth interval in months as short (<36 months) or long (≥ 60 months) birth intervals for our analysis; where the birth interval of 36–59 months was the reference category.

Covariates

Covariates included maternal age at childbirth (19 years or below, 20-34 years and 35 years or more), maternal education (no education, primary and secondary or higher), birth order (2-3, ≥4), maternal Body Mass Index (BMI) (underweight, average, overweight and obese), area of residence (urban and rural), wealth index (poorest quintile, second quintile, middle quintile and richest quintile), maternal employment status during survey (not working and working), desire for pregnancy (yes and no), ever use of contraception (yes and no), number of Antenatal Care (ANC) visits (none, 1-3 visits and ≥4 visits), ANC by Skilled Birth Attendants (SBA) (yes and no), history of any previous loss of pregnancy (yes and no), sex of baby (female and male) and region (Dhaka, Barisal, Chittagong, Khulna, Rajshahi, Rangpur and Sylhet).

We constructed the wealth index variable using principle component analysis through ranking the available wealth variables in the pooled BDHS dataset such as housing materials, type of toilet facility, source of drinking water, type of cooking fuel, availability of electricity, ownership of assets (radio, television, fridge etc.), adjusted for urban-rural differences. We constructed the 'ever use of contraception' variable from calendar data of women's dataset for each year, where ever use of contraception was recorded if there was any contraceptive practice at anytime.

Data analysis

The 'first-day neonatal mortality' and 'early neonatal mortality' variables were calculated from the birth history data, where age at death was recorded in days if they were less than 30 days old. 'Small birth size' was calculated from the birth history data, based on the perceptions of mothers about their infant's birth size. Frequencies with weighted percentage were calculated for the selected variables to describe the characteristics of the women who had a 'first-day neonatal death', an 'early neonatal death' and a 'small birth size baby'. We conducted bivariate analysis to ascertain the association between each of the independent variables and each outcome separately, and multivariable analysis was performed to obtain the adjusted odds ratio (aOR). The wald test was used to assess statistical significance with 95% confidential intervals (CI). The association was adjusted for potential confounders including maternal age at childbirth, birth order, maternal education, maternal wealth index, maternal employment status, area of residence, maternal BMI, maternal desire of pregnancy, ever use of contraceptive method, number of ANC visits, ANC by SBA, history of previous pregnancy loss, sex of infant and region. We followed the direct life table approach to calculate first-day and early neonatal mortality rates per 1000 live births. All analyses were carried out using STATA version 14.2. The 'svy' command was used to calculate the weighted values.

We obtained permission from Monitoring and Evaluation to Assess and Use Results Demographic and Health Surveys (MEASURE DHS) to download the data from the DHS online archive. Ethics approval was not required for our analyses', as the data were anonymous and publicly available.

Patient involvement

No patients were involved in this study.

Figure 1: Flow diagram showing sample selection for first-day neonatal mortality, early neonatal mortality and small birth size analysis

RESULTS

Over the six surveys, and approximately 18 years of data, a total of 42, 718 live births were recorded who were born to the mothers aged 15-49 years within the five years preceding the surveys with a high response (approximately 98%) (Figure 1). From the year 1996 to 2014, there was a substantial decrease in the rate of overall early neonatal mortality (30.5 vs. 23.3 deaths per 1000 live births), but in terms of first-day neonatal mortality, we did not find any consistent decrease, rather the rate has increased from 9.3 deaths in 1996 to 10.6 deaths in 2014 per 1000 live births (Figure 2). Rates of all three adverse pregnancy outcomes were highest among the first-born infants followed by the infants whose births were spaced less than 36 months (Figure 3).

There were 33, 973 singleton live-born infants, most recently born to the mothers within the five years preceding each survey. Of those, 10,722 (32%) were first-born infants who were ineligible as there was no birth interval, which left 21,382 non-first singleton live-born infants in our final analysis for first-day and early neonatal mortality. For small birth size, our analysis consisted of 11,022 singleton live-born children, for the years 1999-2000, 2011 and 2014, as the information regarding small birth size was not available for the surveys in 1996-1997, 2004 and 2007.

Of the 21,382 non-first singleton most recently live-born infants of six surveys, there were 115 first-day and 274 early neonatal deaths. Of 11,022 non-first singleton most recently live-born infants of three surveys, there were 2002 infants with a birth size smaller than average.

Figure 2: Trends in first-day and early neonatal mortality by year of survey (1996-2014)

Figure 3: First-day neonatal mortality, early neonatal mortality rates per 1000 live births and the proportion of small birth size by preceding birth intervals

First-day neonatal mortality

Nearly half of the infants who died on the first-day (n=49) were born following a short birth interval, another 44 infants who died on day '0' (36.0%) were born following a long birth interval. Overall, mothers of the infants who died on the day '0' were more frequently aged between 20 and 34 years (67.5%, n=82), did not have any formal education (36.4%, n=40), had a parity 2-3 (63.3%, n=73), had an average BMI (59.2%, n=67), lived in a rural area (79.2%, n=80) and the infant was male (64.1%, n=74) (Table 1).

Early neonatal mortality

A large proportion of deaths in the early neonatal period was attributable to day '0' deaths (42.8%, n=115). Approximately 45% of infants (n=122) who died within 7 days of birth were born following a short birth interval. Also, a relatively higher proportion (29% vs. 26%) of early neonatal deaths had a long birth interval compared to the recommended birth interval (36-59 months). The socio-demographic characteristics of the mothers of the infants who died in the early neonatal period was quite similar to the day '0' findings, and the proportion of early neonatal mortality was highest among infants born to mothers aged 20-34 years (71.5%, n=200), had a parity 2-3 (60.0%, n=163), did not have any formal education (42.0%, n=116), lived in a rural area (81.0%, n=193), had an average BMI (58.4%, n=156), did not have any ANC (55.2%, n=146) and the infant was male (58.0%, n=162) (Table 1).

Small birth size

More than one-third of infants with a small birth size (34.6%, n=698) were born with a short birth interval. A similar proportion of infants with a small birth size (34.2%, n=694) were born with a long birth interval. The highest proportion of infants perceived as small birth size were born to the mothers aged 20-34 years (80.0%, n=1599), had a parity 2-3 (65.8%, n=1322), had no formal education (38.3%, n=751), had an average BMI (54.4%, n=1069), lived in rural area (79.9%, n=1445), did not have any ANC (51.4%, n=998) and the infant was female (55.1%, n=1059) (Table 1).

Association of birth intervals with first-day neonatal mortality

In the multivariable analysis, both short and long birth intervals were associated with the increased odds of first-day neonatal death. Compared to infants born following a birth interval of 36-59 months, infants with a short birth interval were 2.11 times more likely to die within 24 hours of life (95% CI: 1.17, 3.78). We also found that infants born after a long birth interval, compared to those born following a birth interval of 36-59 months had a 2.02 times higher odds of dying within 24 hours of life (95% CI: 1.10, 3.73). In terms of other determinants, maternal age at childbirth of 19 years or less (aOR: 2.51, 95% CI: 1.35, 4.66), maternal non-use of contraception (aOR: 2.20, 95% CI: 1.32, 3.68) and male infants (aOR: 1.70, 95% CI: 1.09, 2.64) were associated with the increased odds of first-day neonatal death (Table 2).

Association of birth intervals with early neonatal mortality

After adjustment for potential confounders, early neonatal mortality was associated with a short birth interval, while for long birth intervals there was no association. Compared to the infants with a birth interval of 36-59 months, infants born with a short birth interval had 1.58 times higher odds of dying within 7 days of life (95% CI: 1.13, 2.22). Though the odds of early neonatal mortality after a long birth interval compared to the reference group were greater, there was no association (aOR: 1.23, 95% CI: 0.84, 1.81). Other determinants of early neonatal mortality included maternal age 19 years or less (aOR 1.53, 95% CI: 1.02, 2.28), maternal non-use of contraception (aOR: 1.89, 95% CI: 1.35, 2.64) and being a male infant (aOR: 1.32, 95% CI: 1.01, 1.73) (Table 2).

Association of birth intervals with small birth size

Long birth intervals appeared to be associated with the increased odds of small birth size compared to the reference birth interval (aOR: 1.17, 95% CI: 1.02, 1.34), while for short birth intervals, the odds of small birth size were smaller (aOR: 1.04, 95% CI: 0.89, 1.20) compared to the reference birth interval. Other factors associated with small birth size were mothers being classified as poorest (aOR: 1.30, 95% CI: 1.05, 1.61), second poorest (aOR: 1.34, 95% CI: 1.09, 1.64) on wealth index, mothers being underweight by BMI (aOR: 1.19, 95% CI: 1.05, 1.34) and maternal non-use of contraception (aOR: 1.23, 95% CI: 1.06, 1.42). Unlike first-day and early neonatal mortality, male infants were less likely to be born small (aOR: 0.71, 95% CI: 0.63, 0.80) compared to female infants (Table 2).

262 A history of pregnancy loss can be a determinant of birth interval and we therefore restricted our analysis to the children whose mothers had a history of pregnancy loss for all three outcomes. However, we found no relationship for either short or long birth intervals with all three outcomes, though for both short and long birth intervals there was an increase in the odds for first-day and early neonatal death (Table 3).

DISCUSSION

This is a large cross-sectional study of a large sample size over an 18-year time period. There was a marked decline in the overall rate of early neonatal mortality between the year 1996 and 2014, whereas the rate of first-day neonatal death slightly increased. A major proportion of infants who died on the first-day, or in the first week or with a small birth size were born before the recommended optimal period of birth interval (36–59 months). We found that a birth-to-birth interval shorter than 36 months was associated with an increased odds of multiple adverse pregnancy outcomes including first-day neonatal mortality and early neonatal mortality. Also, birth-to-birth interval longer than 59 months was associated with an increased odds of first-day neonatal mortality and small birth size.

Several studies have reported the association of a short birth interval with perinatal or neonatal mortality.[15 16] However, to the best of our knowledge, no prior research has examined the effect of birth interval on first-day neonatal mortality individually. We found that a short birth-to-birth interval of less than 36 months was associated with higher odds of first-day neonatal mortality. Further, we found that the odds of early neonatal mortality were also greater among infants who were born following a short birth interval. This is consistent with the findings of a few earlier investigations from LMIC's which examined the effect of short birth intervals on perinatal, early neonatal or neonatal mortality.[15 16] Similar to our findings, a previous study conducted in India reported an association of neonatal death with a birth interval of less than 36 months (aOR: 1.78, 95% CI: 1.63, 1.94), compared to births spaced 36–59 months.[16] Again, an analysis of 47 Demographic Health Surveys from LMIC also supports our finding of higher odds of early neonatal mortality for short birth intervals, though this analysis has used a slightly different definitions of both short (<24 months) and the reference category birth interval (24-<60 months).[17] Also, our finding is in line with the finding of a previous study conducted in Matlab, Bangladesh, where they reported an increased risk of very short birth intervals (less than 15 months) on early neonatal mortality compared to those born after 36-59 months, though in their study the risk of early neonatal mortality goes down as the birth interval increases up to a minimum of 24-59 months, which is not consistent with our findings.[12] Furthermore, we did not find any significant association between short birth interval and small birth size, although infants born following a short interval were at increased odds of being born with a small birth size. In the BDHS, birthweight is not routinely collected and birth size is based on maternal perception which could lead to some errors in the estimation of small birth size and may be responsible for this non-association. However, the direction of the effect is consistent with several earlier investigations including a meta-analysis of 69 studies from both developing and developed countries.[4 15 18] Several hypotheses have been proposed to explain the association of short birth interval on adverse pregnancy outcomes.[19] One of the most frequently used hypotheses is the maternal nutritional depletion phenomenon, which has been defined by Winkvist et al. as a negative change in maternal nutritional status during a reproductive cycle, mostly due to the biological competition between mother and the growing fetus.[20-22] Short birth spacing does not allow mothers sufficient time to restore nutritional reserves needed to support fetal growth and development during the subsequent pregnancy. This eventually causes maternal nutritional depletion that leads to the increase risk of adverse pregnancy outcomes among the births spaced after a short interval. Another explanation is that the association of short birth intervals and adverse pregnancy outcomes could be confounded by other factors including young maternal age, lower socio-economic status and lower utilisation of health services.[23 24] In our analysis, after adjusting for maternal age, socio-economic factors, and maternal characteristics as well as health service related factors, short birth interval remained associated with first-day and early neonatal mortality which is in line with other studies from both LMIC and high income countries which controlled for similar variables.[12 14 25 26]

Our study further identified the association of long birth interval with adverse perinatal outcomes and found that infants born after a long birth interval were associated with greater odds of first-day neonatal mortality. The effect of long birth interval for early neonatal mortality was also greater but was not significant. There are only a few published studies on the effect of a long birth interval on adverse pregnancy outcome in LMIC and the results are conflicting.[4 15 16] In contrast to our findings, a previous investigation conducted in India, which examined the effect for long birth intervals for perinatal death, did not find any association,[15] and a pooled analysis of 47 Demographic Health Surveys examined the effect of longer interval for neonatal mortality and found that the odds were lower for the longer preceding birth intervals (≥60 months) (OR: 0.80, 95% CI: 0.67, 0.95) compared to the birth interval of 24-<60 months.[17] The inconsistency in findings could be attributed to methodological differences in both the reference category (36-59 months vs. 24-<60 months) of the main exposure variable and the difference in the outcome variable (early neonatal mortality vs. neonatal mortality). However, our findings are consistent with a meta-analysis which reported higher odds of early neonatal mortality with a longer interval,[4] and Rutstein's study which analysed data from 17 developing countries with the same finding.[9] Again, we found that a long birth interval was associated with a greater odds of small birth size. This is similar to a few prior studies which also reported the detrimental effect of a long birth interval on birth size.[4 15 27] The increased odds of adverse pregnancy outcomes for long birth intervals may be due to some concurrent factors such as advanced maternal age and previous history of pregnancy loss. In an earlier investigation, Zhu et al. explained the association between long birth intervals and adverse pregnancy outcomes through the gradual decline in the maternal physiological and anatomical capacities of the reproductive system, hypothesising that if a woman does not conceive for an extended time after a delivery, her physiological characteristics may return to her primigravid state.[28]

We also examined disparities in first-day neonatal mortality, early neonatal mortality and small birth size by several other important factors. Consistent with several previous studies from LMIC's including Bangladesh, we found that young maternal age, maternal non-use of contraception and male sex of infant were associated with greater odds of first-day and early neonatal mortality.[29 30] Regarding small birth size, the two poorest quintiles, maternal underweight, maternal non-use of contraception and female sex of infant were determinants of small birth size, similar to previous investigations.[31 32]

Strengths and limitations

The main strength of our study is that it was based on a large nationally representative sample from six surveys within an 18-year time period in a single country which would improve the homogeneity of the data. We restricted our analysis to the most recent live births within the five years prior to the interview date to minimise recall bias. Furthermore, we were able to add a number of potential confounding factors. We acknowledge some methodological limitations. First, this is a cross-sectional data, which may limit the identification of a causal relationship between the birth interval and adverse pregnancy outcomes. Secondly, BDHS data relies on maternal recall and report of the information regarding preceding birth intervals and the days of infant deaths, which is subject to recall bias. There is a possibility of underreporting of infant deaths, as birth histories and infant survival information were only collected from surviving mothers and there is a strong association between maternal and infant deaths. Also, in our analysis, we were unable to include the variable regarding the history of immediate previous adverse outcome such as stillbirth, miscarriage etc. which is a major determinant of adverse perinatal outcomes in the subsequent pregnancy. Also, previous adverse pregnancy outcome has an influence on birth interval; as mothers who had a previous pregnancy loss may rush into a pregnancy without properly recovering from the pregnancy loss. A previous investigation conducted in Bangladesh, reported that a short birth interval increases the risk of neonatal death of the subsequent infant after a previous adverse neonatal death.[33] We were able to include the variable 'ever had a pregnancy loss' in our analysis, but none of our outcome variables was significant, though stratifying by that variable increased the effect sizes of first-day and early neonatal mortality for both short and long birth intervals.

CONCLUSIONS

Our analysis supports the reduced risk of adverse pregnancy outcomes following a birth-to-birth interval of 36-59 months which is consistent with the WHO recommendation of a birth-to-pregnancy interval of 24 months. Our results highlight several important implications for care-providers, program managers and policymakers by suggesting that a preceding birth interval of 36-59 months could prevent adverse pregnancy outcomes including first-day neonatal death, early neonatal death and low birthweight. Promoting an optimal birth interval of 36-59 months in postpartum family planning is needed.

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Authors' contributions

MKN, CRG and AA conceptualised and designed the study. MKN performed the literature review. MKN, CRG, MTI and TH performed statistical analysis. MKN and CRG drafted the manuscript. MKN and CRG contributed to the interpretation of the data. CRG, AA and MTI contributed to the critical revision of the manuscript. All the authors read and approved the final manuscript.

Conflict of interest

We declare that we have no conflict of interest.

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Table 1: First-day neonatal mortality, early neonatal mortality and small birth size infants by maternal characteristics in Bangladesh: BDHS 1996-2014

Predictors	First-day neonatal mortality (N= 21,382) n (%) n=115	Early neonatal mortality (N= 21,382) n (%) n=274	Small birth size (N= 11,022) n (%) n=2,002
Preceding birth interval in months			
<36 months	49 (45.2)	122 (45.2)	698 (34.6)
36-59 months	22 (18.8)	70 (26.2)	610 (31.2)
≥ 60 months	44 (36.0)	82 (28.6)	694 (34.2)
Mother's age at childbirth			
≤19 years	20 (21.1)	40 (16.2)	218 (10.7)
20-34 years	82 (67.5)	200 (71.5)	1599 (80.0)
≥35 years	13 (11.4)	34 (12.3)	185 (9.3)
Birth order			
2-3	73 (63.3)	163 (60.0)	1322 (65.8)
≥4	42 (36.7)	111 (40.0)	680 (34.2)
Maternal education			
None	40 (36.4)	116 (42.0)	751 (38.3)
Primary	41 (33.7)	84 (30.6)	618 (29.0)
Secondary or higher	34 (29.9)	74 (27.4)	633 (32.7)
Wealth index			
Poorest quintile	24 (19.6)	71 (23.5)	428 (19.6)
Second quintile	24 (21.6)	63 (24.0)	394 (19.8)
Middle quintile	24 (19.5)	57 (22.2)	389 (19.4)
Fourth quintile	20 (20.2)	35 (13.5)	388 (20.7)
Richest quintile	23 (19.1)	48 (16.8)	403 (20.5)
Employment status			
Currently working	34 (32.1)	70 (28.0)	339 (18.0)
Not working	81 (67.9)	204 (72.0)	1663 (82.0)
Area of residence			
Urban	35 (20.8)	81 (19.0)	557 (20.1)
Rural	80 (79.2)	193 (81.0)	1445 (79.9)
Maternal BMI			
Underweight	27 (23.1)	83 (29.3)	711 (35.3)
Average	67 (59.2)	156 (58.4)	1069 (54.5)
Overweight	16 (13.1)	26 (9.3)	169 (7.9)
Obese	5 (4.6)	9 (3.0)	53 (2.3)
Maternal desire of			

pregnancy			
Yes	77 (63.3)	171 (63.5)	1205 (60.1)
No	38 (36.7)	103 (36.5)	797 (39.9)
Ever use of contraception			
Yes	81 (72.9)	196 (71.9)	1605 (81.1)
No	34 (27.1)	78 (28.1)	397 (18.9)
No. of ANC visits			
None	48 (43.1)	146 (55.2)	998 (51.4)
1-3 visits	46 (40.7)	90 (32.0)	683 (33.7)
≥4 visits	21 (16.2)	38 (12.8)	321 (14.9)
ANC by SBA			
Yes	56 (47.3)	111 (38.6)	817 (38.8)
No	59 (52.7)	163 (61.4)	1185 (61.2)
History of any previous pregnancy loss			
Yes	35 (26.3)	79 (26.2)	435 (21.4)
No	80 (73.7)	195 (73.8)	1567 (78.6)
Sex of infant			
Male	74 (64.1)	162 (58.0)	943 (44.9)
Female	41 (35.9)	112 (42.0)	1059 (55.1)
Region			
Barisal	10 (4.2)	28 (5.5)	176 (4.7)
Chittagong	12 (10.1)	40 (13.9)	463 (25.4)
Khulna	10 (8.2)	27 (9.0)	232 (8.6)
Rajshahi	27 (25.1)	50 (20.9)	227 (13.2)
Rangpur	15 (8.0)	47 (10.7)	235 (8.2)
Sylhet	10 (3.5)	18 (3.5)	281 (7.1)
Dhaka	31 (40.9)	64 (36.5)	388 (32.8)
Year of survey			
1996	16 (14.0)	45 (15.8)	-
1999	13 (10.7)	45 (15.8)	705 (34.2)
2004	22 (20.1)	55 (21.2)	-
2007	19 (17.9)	37 (13.6)	-
2011	29 (24.1)	59 (21.5)	813 (40.1)
2014	16 (13.2)	33 (12.1)	484 (25.7)

Table 2: Adjusted odds ratios for the association between preceding birth intervals and adverse pregnancy outcomes in Bangladesh: BDHS 1996-2014

Predictors	First-day neonatal mortality N=21,382		Early neonatal mortality N=21,382		Small birth size N=11,022	
	aOR (95% CI)	P value	aOR (95% CI)	P value	aOR (95% CI)	P value
Preceding birth interval in months						
<36 months	2.11 (1.17, 3.78)	<0.05	1.58 (1.13, 2.22)	<0.05	1.04 (0.90, 1.20)	0.08
36-59 months	Reference		Reference		Reference	
≥60 months	2.02 (1.10, 3.73)		1.23 (0.84, 1.81)		1.17 (1.02, 1.34)	
Mother's age at childbirth						
≤19 years	2.51 (1.35, 4.66)	<0.05	1.53 (1.02, 2.28)	<0.05	1.01 (0.83, 1.21)	0.68
20-34 years	Reference		Reference		Reference	
≥35 years	1.34 (0.67, 2.69)		1.46 (0.93, 2.29)		1.10 (0.89, 1.36)	
Birth order						
2-3	Reference		Reference		Reference	
≥4	1.48 (0.88, 2.50)	0.14	1.27 (0.92, 1.75)	0.15	1.02 (0.89, 1.16)	0.81
Maternal education						
None	0.97 (0.49, 1.94)	0.80	0.94 (0.60, 1.46)	0.94	1.09 (0.91, 1.30)	0.05
Primary	1.15 (0.62, 2.11)		0.98 (0.65, 1.50)		0.91 (0.77, 1.07)	
Secondary or higher	Reference		Reference		Reference	
Wealth status						
Poorest quintile	0.76 (0.34, 1.68)	0.89	0.86 (0.53, 1.40)	0.68	1.30 (1.05, 1.61)	<0.05
Second quintile	0.92 (0.43, 1.95)		0.99 (0.61, 1.63)		1.34 (1.09, 1.64)	
Middle quintile	0.97 (0.48, 1.96)		1.09 (0.70, 1.72)		1.12 (0.91, 1.37)	
Fourth quintile	1.15 (0.58, 2.28)		0.80 (0.48, 1.32)		1.12 (0.93, 1.37)	

Richest quintile	Reference		Reference		Reference	
Employment status						
Working	1.59 (0.99, 2.56)	0.05	1.30 (0.96, 1.75)	0.09	1.02 (0.87, 1.19)	0.83
Not working	Reference		Reference		Reference	
Area of residence						
Urban	1.10 (0.64, 1.88)	0.72	1.14 (0.80, 1.63)	0.46	1.09 (0.93, 1.27)	0.28
Rural	Reference		Reference		Reference	
Maternal BMI						
Underweight	0.58 (0.35, 0.97)	<0.05	0.70 (0.52, 0.94)	0.05	1.19 (1.05, 1.34)	<0.05
Average	Reference		Reference		Reference	
Overweight	1.81 (0.90, 3.65)		1.36 (0.80, 2.32)		0.86 (0.70, 1.07)	
Obese	1.84 (0.59, 5.67)		1.23 (0.53, 2.89)		0.86 (0.60, 1.23)	
Maternal desire of pregnancy						
Yes	1.09 (0.71, 1.68)	0.68	1.13 (0.84, 1.51)	0.43	0.92 (0.81, 1.05)	0.22
No	Reference		Reference		Reference	
Ever use of contraception						
Yes	Reference		Reference		Reference	
No	2.20 (1.32, 3.68)	<0.05	1.89 (1.35, 2.64)	<0.001	1.23 (1.06, 1.42)	<0.05
No of ANC visits						
None	0.89 (0.29, 2.73)	0.62	1.61 (0.74, 3.48)	0.48	1.09 (0.84, 1.42)	0.79
1-3 visits	1.21 (0.61, 2.37)		1.16 (0.71, 1.89)		1.03 (0.86, 1.23)	
≥4 visits	Reference		Reference		Reference	
ANC by SBA						
Yes	Reference		Reference		Reference	

No	1.01 (0.46, 2.19)	0.99	0.78 (0.43, 1.42)	0.42	1.05 (0.83, 1.32)	0.70
History of any previous pregnancy loss						
Yes	1.31 (0.85, 2.03)	0.22	1.27 (0.94, 1.71)	0.12	1.04 (0.91, 1.20)	0.53
No	Reference		Reference		Reference	
Sex of infant						
Male	1.70 (1.09, 2.64)	<0.05	1.32 (1.01, 1.73)	<0.05	0.71 (0.63, 0.80)	<0.001
Female	Reference		Reference		Reference	
Region						
Barisal	0.59 (0.27, 1.30)	<0.05	0.82 (0.51, 1.30)	<0.05	0.74 (0.59, 0.92)	<0.001
Chittagong	0.34 (0.16, 0.71)		0.50 (0.32, 0.77)		1.16 (0.97, 1.38)	
Khulna	0.72 (0.35, 1.50)		0.91 (0.57, 1.44)		0.96 (0.79, 1.17)	
Rajshahi	1.12 (0.63, 1.99)		1.02 (0.68, 1.53)		0.73 (0.60, 0.89)	
Rangpur	0.68 (0.35, 1.29)		0.99 (0.66, 1.51)		0.81 (0.65, 0.99)	
Sylhet	0.83 (0.36, 1.88)		0.92 (0.53, 1.61)		1.24 (1.03, 1.50)	
Dhaka	Reference		Reference		Reference	

*Odds ratios were adjusted for maternal age at childbirth, birth order, maternal education, maternal wealth index, maternal employment status, area of residence, maternal BMI, maternal desire of pregnancy, ever use of contraceptive method, number of ANC visits, ANC by SBA, history of any previous pregnancy loss, sex of infant and region

Table 3: Adjusted odds ratios for the association between preceding birth intervals and adverse pregnancy outcomes by history of pregnancy loss: BDHS 1996-2014

Predictors	First-day neonatal mortality N=21,382		Early neonatal mortality N=21,382		Small birth size N=11,022	
	aOR (95% CI)	P value	aOR (95% CI)	P value	aOR (95% CI)	P value
Preceding birth interval in months*history of pregnancy loss						
<36 months	2.12 (0.74, 6.13)	0.28	1.77 (0.90, 3.49)	0.19	0.96 (0.69, 1.33)	0.38
36-59 months	Reference		Reference		Reference	
≥60 months	2.15 (0.73, 6.31)		1.74 (0.84, 3.62)		1.18 (0.87, 1.59)	

*Odds ratios were adjusted for maternal age at childbirth, birth order, maternal education, maternal wealth index, maternal employment status, area of residence, maternal BMI, maternal desire of pregnancy, ever use of contraceptive method, number of ANC visits, ANC by SBA, sex of infant and region

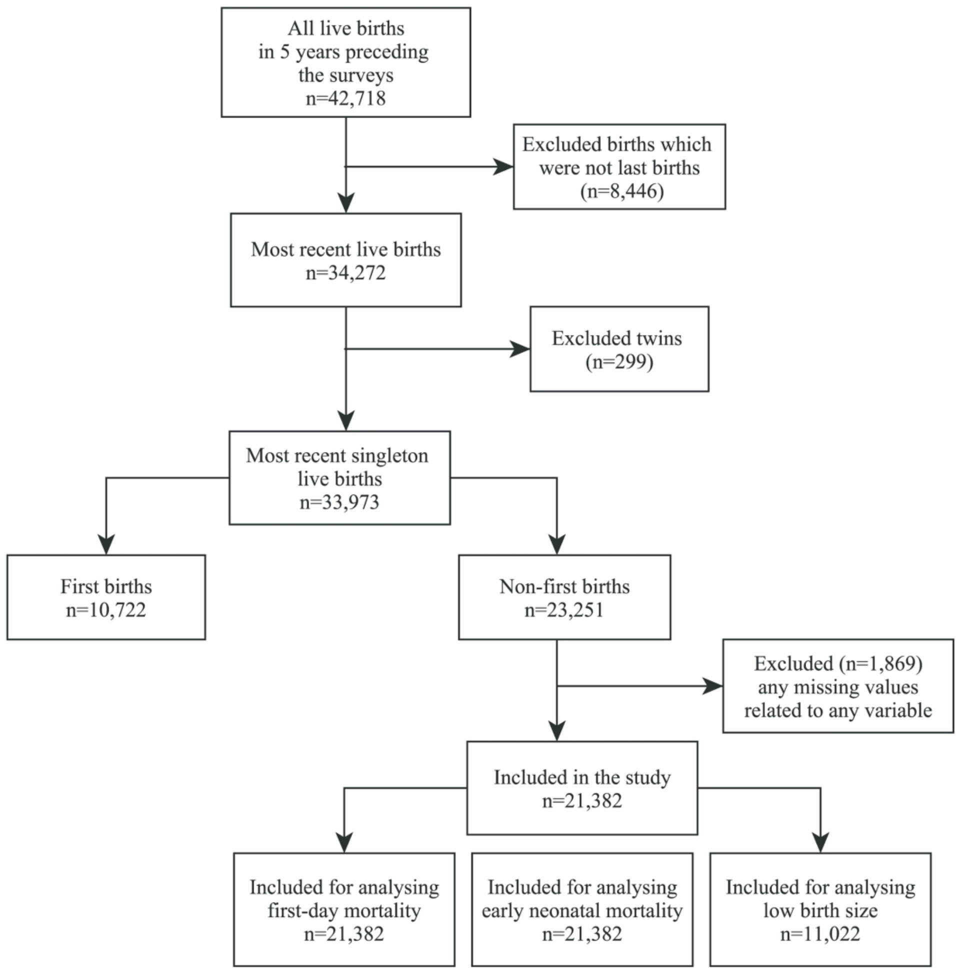

Figure 1: Flow diagram showing sample selection for first-day neonatal mortality, early neonatal mortality and small birth size analysis

203x205mm (300 x 300 DPI)

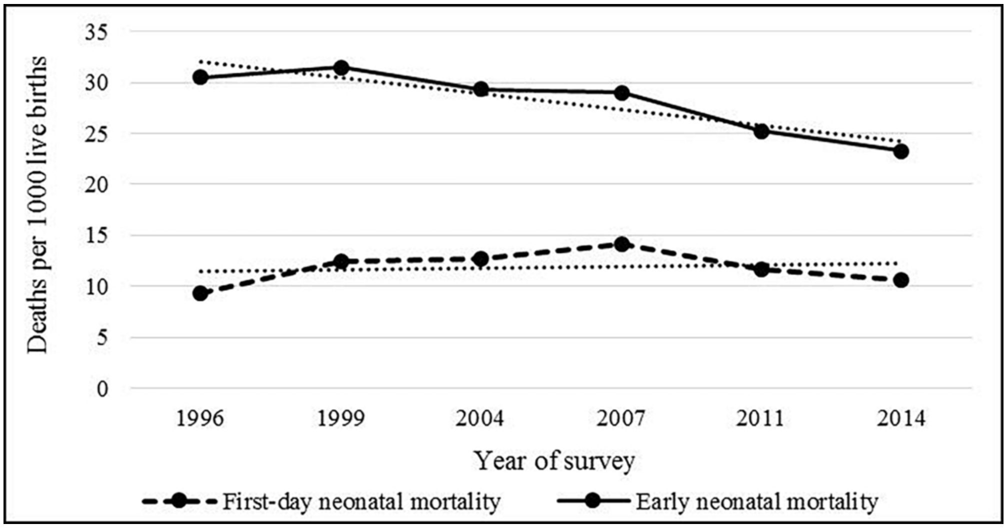

Figure 2: Trends in first-day and early neonatal mortality by year of survey (1996-2014)

191x99mm (300 x 300 DPI)

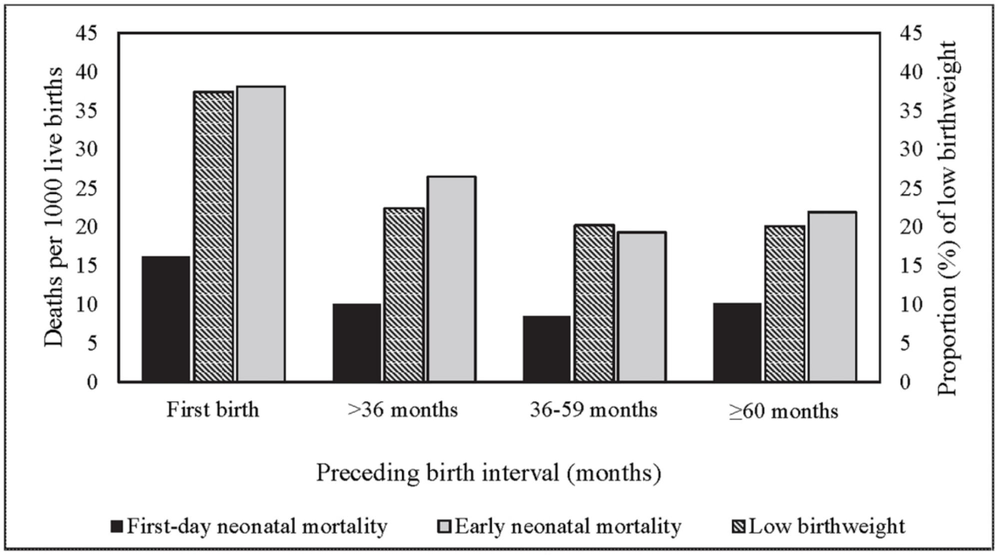

Figure 3: First-day neonatal mortality, early neonatal mortality rates per 1000 live births and the proportion of small birth size by preceding birth intervals

178x99mm (300 x 300 DPI)

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Risk of adverse pregnancy outcomes associated with short and long birth intervals in Bangladesh: evidence from six Bangladesh Demographic and Health Surveys, 1996-2014

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Risk of adverse pregnancy outcomes associated with short and long birth intervals in Bangladesh: evidence from six Bangladesh Demographic and Health Surveys, 1996-2014

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ABSTRACT

Objective

To examine the effect of short (<36 months) and long (≥60 months) birth intervals on adverse pregnancy outcomes in Bangladesh.

Design, setting and participants

We analysed data from six Bangladesh Demographic and Health Surveys (1996-1997, 1999-2000, 2004, 2007, 2011 and 2014). We included all singleton non-first live births, most recently born to the mothers within five years preceding each survey (n=21,382). We defined birth interval according to previous literature which suggests that a birth interval between 36 and 59 months is the most ideal interval. Bivariate and multivariable analyses were conducted to obtain the crude and adjusted odds ratio (aOR) respectively to assess the odds of first-day neonatal death, early neonatal death and small birth size for both short (<36 months) and long (≥60 months) spacing between births.

Main outcome measures

First-day neonatal death, early neonatal death and small birth size.

Results

In the multivariable analysis, compared to births spaced 36-59 months, infants with birth intervals of less than 36 months were associated with the increased odds of first-day neonatal death (aOR: 2.11, 95% CI: 1.17, 3.78) and early neonatal death (aOR: 1.58, 95% CI: 1.13, 2.22). Compared to births spaced 36-59 months, infants with birth interval of ≥60 months, were associated with the increased odds of first-day neonatal death (aOR: 2.02, 95% CI: 1.10, 3.73) and small birth size (aOR: 1.17, 95% CI: 1.02, 1.34). When there was a history of any previous pregnancy loss, there was an increase in the odds of first-day and early neonatal death for both short and long birth intervals, although there was no association.

Conclusions

Birth intervals shorter than 36 months and longer than 59 months are associated with the increased risk of adverse pregnancy outcomes. Care-providers, program managers and policymakers should focus on promoting the optimal birth interval between 36-59 months in postpartum family planning.

Key words: Pregnancy outcome, birth interval, first-day neonatal death, early neonatal death, small birth size, Bangladesh

Strengths and limitations of this study

- The main strength of this study is the use of a large sample from six nationally representative surveys of Bangladesh with a very high response (98%).
- We used the information of the most recent births within the 5 years preceding the surveys in order to minimise recall bias.
- Our study is the first in Bangladesh which analysed the effect of birth intervals and other risk factors for first-day neonatal mortality.
- Demographic and Health Survey data is cross-sectional, which reduces the ability to infer causation.
- Demographic and Health Survey data uses maternal perceptions of infant birth size as a proxy for birthweight which may be a limitation.

BACKGROUND

Adverse pregnancy outcomes such as stillbirth, early neonatal mortality and low birthweight are of considerable public health significance. Globally, perinatal mortality (stillbirth and early neonatal mortality) accounts for more than 6 million deaths every year. Of those, approximately 2 million newborns die in the early neonatal period.[1] The risk is greatest on the first day of life, approximately 1 million newborns die within the first 24 hours.[1] Further, low birthweight, occurs in more than 20 million newborns worldwide, which is a major indicator of perinatal mortality and contributes to up to 80% of neonatal mortality.[2] The greatest proportion of perinatal deaths and low birthweight (97-99%) occur in Low and Middle-Income Countries (LMIC).[3]

Several interventions have been suggested to address adverse pregnancy outcomes, such as pregnancy spacing.[4] Both short and long birth intervals have been reported to be associated with an increased risk of a number of adverse perinatal outcomes.[5 6] Current World Health Organization (WHO) guidelines recommend an interval of at least 24 months before attempting the next pregnancy after a live birth (i.e. birth-to-pregnancy interval) in order to reduce any adverse pregnancy outcomes.[7] Thus, the birth-to-birth interval should be at least 33 months by including nine months of pregnancy to the recommended 24 months.[8] In an analysis of Demographic and Health Survey data from 17 developing countries, Rutstein suggested that the optimal birth interval should be between 36 and 59 months as each birth interval less than 36 and more than 59 months showed a tendency towards neonatal mortality and morbidity.[9] The WHO highlighted the necessity of future research investigating the association between birth interval and adverse pregnancy outcomes.[7]

Bangladesh has high perinatal mortality (44 per 1000 pregnancies) and morbidity,[10] where birth spacing remains a problem.[11] Between the year 1993 and 2014, though the median birth interval increased by 49% (from 35 months to 52 months), approximately 30% of non-first births occurred within less than 36 months (7 months to 35 months) following the previous birth.[10] However, another 40% of non-first births occurred following a birth interval of more than 59 months.[10] Of the papers investigating birth interval in Bangladesh, most have focussed on the effect of short birth interval and have not considered a long birth interval as a risk of adverse perinatal outcome.[12 13] Given the changing demographics in Bangladesh and increase in proportion of longer birth intervals, our objective therefore was to examine whether the preceding birth interval (short or long) was independently associated with increased risk of adverse pregnancy outcomes including first-day neonatal mortality, early neonatal mortality and low birthweight using pooled data from the Bangladesh Demographic and Health Surveys (BDHS).

METHODS

Data source

We used the BDHS data from the years; 1996-1997, 1999-2000, 2004, 2007, 2011 and 2014. BDHS is a nationally representative household survey carried out every three to four years under the authority of the National Institute of Population Research and Training of the Ministry of Health and Family Welfare. The survey employed a two-stage stratified cluster-sampling design with rural and urban samples to collect information from ever-married women aged 15-49 years and ever-married men 15-54 years about demographic and health status. Data were obtained from the website; www.measuredhs.com. The BDHS consists of three types of questionnaires: household, women, and men. Our analysis was limited to the information obtained from the women's and household questionnaires. We pooled the data files from six surveys into a dataset and analysed the live births occurring during the five years preceding the surveys. Demographic and Health Survey program employs standardised data collection procedures using standard model questionnaires to ensure consistent content over time and across countries allowing comparability across populations cross-sectionally and over time.[14] We selected six surveys in this pooled analysis based on the similarities in sampling design, comparability of survey questionnaires for focus variables of this analysis, and availability of data for the pooled analysis. In our analysis, we included the data from all singleton, non-first, most recent live-born children within the five years preceding the six BDHSs, 1996-1997, 1999-2000, 2004, 2007, 2011 and 2014.

Outcome variables

We conducted three analyses', with three different outcome variables- 'first-day neonatal death', 'early neonatal death' and 'small birth size'. First-day deaths were defined as deaths during the first 24 hours after birth (day 0) among live-born children and early neonatal deaths were deaths between the age of 0 to 6 days among live-born children. These two outcome variables overlap, but conform to standard definitions. We used 'small birth size' as a proxy for low birthweight. Estimates about birthweight are not collected by the BDHS. 'Mother's perception of the baby's birth size' is routinely used as a proxy indicator of birthweight. For our analysis, we defined 'small birth size' as the birth size of an infant which was perceived as either 'very small' or 'smaller than average'. Each of the outcome variables was considered dichotomous for this analysis as yes (1) or no (0).

Exposure variable

The main exposure variable used in our analysis was the length of the preceding birth interval as a measure of birth spacing. This was measured as the number of months between two successive live births.[9,15] We followed Rutstein's recommendation regarding optimal birth interval of 36-59 months for our analysis.[9] We categorised preceding birth interval in months as short (<36 months) or long (≥ 60 months) birth intervals for our analysis; where the birth interval of 36–59 months was the reference category.

143 **Covariates**

144 Covariates included maternal age at childbirth (19 years or below, 20-34 years and 35 years
145 or more), maternal education (none, primary and secondary or higher), birth order (2-3, ≥4),
146 maternal Body Mass Index (BMI) (underweight, average, overweight and obese), area of
147 residence (urban and rural), wealth index (poorest quintile, second quintile, middle quintile,
148 fourth quintile and richest quintile), maternal employment status during survey (currently
149 working and not working), maternal desire of pregnancy (yes and no), ever use of
150 contraception (yes and no), number of Antenatal Care (ANC) visits (none, 1-3 visits and ≥4
151 visits), ANC by Skilled Birth Attendants (SBA) (yes and no), history of any previous loss of
152 pregnancy (yes and no), sex of baby (female and male) and region (Dhaka, Barisal,
153 Chittagong, Khulna, Rajshahi, Rangpur and Sylhet).

154 We constructed the wealth index variable using principle component analysis through
155 ranking the available wealth variables in the pooled BDHS dataset such as housing materials,
156 type of toilet facility, source of drinking water, type of cooking fuel, availability of
157 electricity, ownership of assets (radio, television, fridge etc.), adjusted for urban-rural
158 differences. We constructed the 'ever use of contraception' variable from calendar data of
159 women's dataset for each year, where ever use of contraception was recorded if there was any
160 contraceptive practice at anytime.

161 **Data analysis**

162 The 'first-day neonatal mortality' and 'early neonatal mortality' variables were calculated
163 from the birth history data, where age at death was recorded in days if they were less than 30
164 days old. 'Small birth size' was calculated from the birth history data, based on the
165 perceptions of mothers about their infant's birth size. Frequencies with weighted percentage
166 were calculated for the selected variables to describe the characteristics of the women who
167 had a 'first-day neonatal death', an 'early neonatal death' and a 'small birth size' infant. We

168 conducted bivariate analysis to ascertain the unadjusted association between each of the independent variables and each outcome separately, and multivariable analysis was performed to obtain the adjusted odds ratio (aOR). All covariates associated with each of outcomes at the p value ≤0.25 in unadjusted analysis were included in the final model of multivariable logistic regression. Also, some other covariates (maternal education, maternal wealth status, maternal area of residence, maternal desire of pregnancy, number of ANC and ANC by SBA) were included in the final model regardless of their significant levels because of being known risk factors of adverse pregnancy outcomes based on several previous literature.[9 16 17 18] We also checked the variables for multicollinearity. The wald test was used to assess statistical significance with 95% confidential intervals (CI). The association was adjusted for potential confounders including maternal age at childbirth, birth order, maternal education, maternal wealth index, maternal employment status, area of residence, maternal BMI, maternal desire of pregnancy, ever use of contraceptive method, number of ANC visits, ANC by SBA, history of any previous pregnancy loss, sex of infant and region. We also restricted our analysis by 'history of any previous pregnancy loss' to assess the combined effect of history of any previous pregnancy loss and birth interval (short or long) on all three outcomes. We followed the direct life table approach to calculate first-day and early neonatal mortality rates per 1000 live births. All analyses were carried out using STATA version 14.2. We used the 'svy' command in all our analyses to calculate the weighted values in order to adjust for the clustering effect and sample stratification.

We obtained permission from Monitoring and Evaluation to Assess and Use Results Demographic and Health Surveys (MEASURE DHS) to download the data from the DHS online archive. Ethics approval was not required for our analyses', as the data were anonymous and publicly available.

192 **Patient involvement**

193 No patients were involved in this study.

194 **Figure 1: Flow diagram showing sample selection for first-day neonatal mortality, early**
195 **neonatal mortality and small birth size analysis**

196 **RESULTS**

197 Over the six surveys, and approximately 18 years of data, a total of 42,718 live births were
198 recorded who were born to the mothers aged 15-49 years within the five years preceding the
199 surveys with a high response (approximately 98%) (Figure 1). From the year 1996 to 2014,
200 there was a substantial decrease in the rate of overall early neonatal mortality (30.5 vs. 23.3
201 deaths per 1000 live births), but in terms of first-day neonatal mortality, we did not find any
202 consistent decrease, rather the rate has increased from 9.3 deaths in 1996 to 10.6 deaths in
203 2014 per 1000 live births (Figure 2). Rates of all three adverse pregnancy outcomes were
204 highest among the first-born infants followed by the infants whose births were spaced less
205 than 36 months (Figure 3).

206 There were 33, 973 singleton live-born infants, most recently born to the mothers within the
207 five years preceding each survey. Of those, 10,722 (32%) were first-born infants who were
208 ineligible as there was no birth interval, which left 21,382 non-first singleton live-born
209 infants in our final analysis for first-day and early neonatal mortality. For small birth size, our
210 analysis consisted of 11,022 singleton live-born children, for the years 1999-2000, 2011 and
211 2014, as the information regarding small birth size was not available for the surveys in 1996-
212 1997, 2004 and 2007 (Figure 1).

213 Of the 21,382 non-first singleton most recently live-born infants of six surveys, there were
214 115 first-day and 274 early neonatal deaths. Of 11,022 non-first singleton most recently live-
215 born infants of three surveys, there were 2002 infants with a birth size smaller than average.

Figure 2: Trends in first-day and early neonatal mortality by year of survey (1996-2014)

Figure 3: First-day neonatal mortality, early neonatal mortality rates per 1000 live births and the proportion of small birth size by preceding birth intervals

First-day neonatal mortality

Nearly half of the infants who died on the first-day (n=49) were born following a short birth interval, another 44 infants who died on day '0' (36.0%) were born following a long birth interval. Overall, mothers of the infants who died on the day '0' were more frequently aged between 20 and 34 years (67.5%, n=82), did not have any formal education (36.4%, n=40), had a parity 2-3 (63.3%, n=73), had an average BMI (59.2%, n=67) and lived in a rural area (79.2%, n=80) (64.1%, n=74) (Table 1).

Early neonatal mortality

A large proportion of deaths in the early neonatal period was attributable to day '0' deaths (42.8%, n=115). Approximately 45% of infants (n=122) who died within 7 days of birth were born following a short birth interval. Also, a relatively higher proportion (29% vs. 26%) of early neonatal deaths had a long birth interval compared to the recommended birth interval (36-59 months). The socio-demographic characteristics of the mothers of the infants who died in the early neonatal period was quite similar to the day '0' findings, and the proportion of early neonatal mortality was highest among infants born to mothers aged 20-34 years (71.5%, n=200), had a parity 2-3 (60.0%, n=163), did not have any formal education (42.0%, n=116), lived in a rural area (81.0%, n=193), had an average BMI (58.4%, n=156) and did not have any ANC (55.2%, n=146) (Table 1).

Small birth size

More than one-third of infants with a small birth size (34.6%, n=698) were born with a short birth interval. A similar proportion of infants with a small birth size (34.2%, n=694) were born with a long birth interval. The highest proportion of infants perceived as small birth size were born to the mothers aged 20-34 years (80.0%, n=1599), had a parity 2-3 (65.8%, n=1322), had no formal education (38.3%, n=751), had an average BMI (54.4%, n=1069), lived in rural area (79.9%, n=1445) and did not have any ANC (51.4%, n=998) (Table 1).

Association of birth intervals with first-day neonatal mortality

In the multivariable analysis, both short and long birth intervals were associated with the increased odds of first-day neonatal death. Compared to infants born following a birth interval of 36-59 months, infants with a short birth interval were 2.11 times more likely to die within 24 hours of life (95% CI: 1.17, 3.78). We also found that infants born after a long birth interval, compared to those born following a birth interval of 36-59 months had a 2.02 times higher odds of dying within 24 hours of life (95% CI: 1.10, 3.73) (Table 2).

Association of birth intervals with early neonatal mortality

After adjustment for potential confounders, early neonatal mortality was associated with a short birth interval, while for long birth intervals there was no association. Compared to the infants with a birth interval of 36-59 months, infants born with a short birth interval had 1.58 times higher odds of dying within 7 days of life (95% CI: 1.13, 2.22). Though the odds of early neonatal mortality were greater for long birth intervals compared to the reference group, there was no association (aOR: 1.23, 95% CI: 0.84, 1.81) (Table 2).

Association of birth intervals with small birth size

Long birth intervals appeared to be associated with the increased odds of small birth size compared to the reference birth interval (aOR: 1.17, 95% CI: 1.02, 1.34), while for short birth intervals, the odds of small birth size were smaller (aOR: 1.04, 95% CI: 0.89, 1.20) compared to the reference birth interval (Table 2).

A history of pregnancy loss can be a determinant of birth interval and we therefore restricted our analysis to the children whose mothers had a history of any previous pregnancy loss for all three outcomes. However, we found no relationship for either short or long birth intervals with all three outcomes, though for both short and long birth intervals there was an increase in the odds for first-day and early neonatal death (Table 3).

DISCUSSION

This study suggests that both short and long birth intervals were associated with the increased odds of adverse pregnancy outcomes. Over the six surveys, a major proportion of infants who died on the first-day, or in the first week or with a small birth size were born before the recommended optimal period of birth interval (36–59 months). We found that a birth-to-birth interval shorter than 36 months was associated with an increased odds of multiple adverse pregnancy outcomes including first-day neonatal mortality and early neonatal mortality. Also, a birth-to-birth interval longer than 59 months was associated with an increased odds of first-day neonatal mortality and small birth size.

Infants born with a short birth-to-birth interval of less than 36 months were associated with higher odds of first-day neonatal mortality. Several studies have reported the association of a short birth interval with perinatal or neonatal mortality.[19 20] However, to the best of our knowledge, no prior research has examined the effect of birth interval on first-day neonatal mortality individually. Further, we found that the odds of early neonatal mortality were also greater among infants who were born following a short birth interval. This is consistent with the findings of a few earlier investigations from LMIC's which examined the effect of short birth intervals on perinatal, early neonatal or neonatal mortality.[19 20] Similar to our findings, a previous study conducted in India reported an association of neonatal death with a birth interval of less than 36 months (aOR: 1.78, 95% CI: 1.63, 1.94), compared to births spaced 36–59 months.[20] Again, an analysis of 47 Demographic Health Surveys from LMIC also supports our finding of higher odds of early neonatal mortality for short birth intervals, though this analysis has used a slightly different definition of both short (<24 months) and the reference category birth interval (24-<60 months).[21] Also, our finding is in line with the finding of a previous study conducted in Matlab, Bangladesh, where they reported an increased risk of very short birth intervals (less than 15 months) on early neonatal mortality compared to those born after 36-59 months, though in their study the risk of early neonatal mortality goes down as the birth interval increases up to a minimum of 24-59 months, which is not consistent with our findings.[12] Furthermore, we did not find any significant association between short birth interval and small birth size, although infants born following a short interval were at increased odds of being born with a small birth size. In the BDHS, birthweight is not routinely collected and birth size is based on maternal perception which could lead to some errors in the estimation of small birth size and may be responsible for this non-association. However, the direction of the effect is consistent with several earlier investigations including a meta-analysis of 69 studies from both developing and developed countries.[4 19 22]

Several hypotheses have been proposed to explain the association of short birth interval on adverse pregnancy outcomes.[23] One of the most frequently used hypotheses is the maternal nutritional depletion phenomenon, which has been defined by Winkvist et al. as a negative change in maternal nutritional status during a reproductive cycle, mostly due to the biological competition between mother and the growing fetus.[24-26] Short birth spacing does not allow mothers sufficient time to restore nutritional reserves needed to support fetal growth and development during the subsequent pregnancy. This eventually causes maternal nutritional depletion that leads to the increase risk of adverse pregnancy outcomes among the births spaced after a short interval. Another explanation is that the association of short birth intervals and adverse pregnancy outcomes could be confounded by other factors including young maternal age, lower socio-economic status and lower utilisation of health services.[27 28] In our analysis, after adjusting for maternal age, socio-economic factors, and maternal characteristics as well as health service related factors, short birth interval remained associated with first-day and early neonatal mortality which is in line with other studies from both LMIC and high income countries which controlled for similar variables.[12 15 29 30]

Our study further identified the association of long birth interval with adverse perinatal outcomes and found that infants born after a long birth interval were associated with greater odds of first-day neonatal mortality. The effect of long birth interval for early neonatal mortality was also greater but was not significant. There are only a few published studies on the effect of a long birth interval on adverse pregnancy outcome in LMIC and the results are conflicting.[4 19 20] In contrast to our findings, a previous investigation conducted in India, which examined the effect for long birth interval for perinatal death, did not find any association,[19] and a pooled analysis of 47 Demographic Health Surveys examined the effect of longer interval for neonatal mortality and found that the odds were lower for the longer preceding birth intervals (≥60 months) (OR: 0.80, 95% CI: 0.67, 0.95) compared to the birth interval of 24-<60 months.[21] The inconsistency in findings could be attributed to methodological differences in both the reference category (36-59 months vs. 24-<60 months) of the main exposure variable and the difference in the outcome variable (early neonatal mortality vs. neonatal mortality). However, our findings are consistent with a meta-analysis which reported higher odds of early neonatal mortality with a longer interval,[4] and Rutstein's study which analysed data from 17 developing countries with the same finding.[9] Again, we found that a long birth interval was associated with a greater odds of small birth size. This is similar to a few prior studies which also reported the detrimental effect of a long birth interval on birth size.[4 19 31]

The increased odds of adverse pregnancy outcomes for long birth intervals may be due to some concurrent factors such as advanced maternal age and previous history of pregnancy loss. In an earlier investigation, Zhu et al. explained the association between long birth intervals and adverse pregnancy outcomes through the gradual decline in the maternal physiological and anatomical capacities of the reproductive system, hypothesising that if a woman does not conceive for an extended time after a delivery, her physiological characteristics may return to her primigravid state.[32]

Strengths and limitations

The main strength of our study is that it was based on a large nationally representative sample from six surveys within an 18-year time period in a single country which would improve the homogeneity of the data. We restricted our analysis to the most recent live births within the five years prior to the interview date to minimise recall bias. Furthermore, we were able to add a number of potential confounding factors.

We acknowledge some methodological limitations. First, this is a cross-sectional data, which may limit the identification of a causal relationship between the birth interval and adverse pregnancy outcomes. Secondly, BDHS data relies on maternal recall and report of the information regarding preceding birth intervals and the days of infant deaths, which is subject to recall bias. Third, there is a possibility of underreporting of infant deaths, as birth histories and infant survival information were only collected from surviving mothers and there is a strong association between maternal and infant deaths. Fourth, we acknowledge a limitation of using maternal perception on birth size instead of birthweight in our analysis due to unavailability of actual estimates of birthweight in BDHS, which may reflect newborn's overall health status rather than birthweight only. Fifth, as we pooled six BDHS datasets over 18 years, there may be a possibility of changes in the background characteristics of the population over 18 years. Also, in our analysis, we were unable to include the variable regarding the history of immediate previous adverse outcome such as stillbirth, miscarriage etc. which is a major determinant of adverse perinatal outcomes in the subsequent pregnancy. A previous investigation conducted in Bangladesh using dynamic panel data models, reported that a previous adverse birth outcome may be subject to ‘scarring effect’ which leads to a short birth interval (replacement) and thus increases the risk of mortality of the subsequent infant (nutritional depletion); as a mother with a previous pregnancy loss may rush into a pregnancy without properly recovering from the pregnancy loss.[33] In our analysis, we were unable to consider the role of ‘scarring effect’ related to a previous adverse pregnancy outcome which has an influence on birth interval. However, we were able to include the variable ‘ever had a pregnancy loss’ in our analysis, but none of our outcome variables was significant, though stratifying by that variable increased the effect sizes of first-day and early neonatal mortality for both short and long birth intervals.

CONCLUSIONS

Our analysis supports the reduced risk of adverse pregnancy outcomes following a birth-to-birth interval of 36-59 months which is consistent with the WHO recommendation of a birth-to-pregnancy interval of 24 months. Our results highlight several important implications for care-providers, program managers and policymakers by suggesting that a preceding birth interval of 36-59 months could prevent adverse pregnancy outcomes including first-day neonatal death, early neonatal death and low birthweight. Promoting an optimal birth interval of 36-59 months in postpartum family planning is needed.

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Authors' contributions

MKN, CRG and AA conceptualised and designed the study. MKN performed the literature review. MKN, CRG, MTI and TH performed statistical analysis. MKN and CRG drafted the manuscript. MKN and CRG contributed to the interpretation of the data. MKN, CRG, AA and MTI contributed to the critical revision of the manuscript. All the authors read and approved the final manuscript.

Conflict of interest

We declare that we have no conflict of interest.

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Data sharing statement

The data are anonymous and publicly available in the website; www.measuredhs.com.

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Table 1: First-day neonatal mortality, early neonatal mortality and small birth size infants by maternal characteristics in Bangladesh: BDHS 1996-2014

Predictors	First-day neonatal mortality (N= 21,382) n (%) n=115	Early neonatal mortality (N= 21,382) n (%) n=274	Small birth size (N= 11,022) n (%) n=2,002
Preceding birth interval in months			
<36 months	49 (45.2)	122 (45.2)	698 (34.6)
36-59 months	22 (18.8)	70 (26.2)	610 (31.2)
≥ 60 months	44 (36.0)	82 (28.6)	694 (34.2)
Mother's age at childbirth			
≤19 years	20 (21.1)	40 (16.2)	218 (10.7)
20-34 years	82 (67.5)	200 (71.5)	1599 (80.0)
≥35 years	13 (11.4)	34 (12.3)	185 (9.3)
Birth order			
2-3	73 (63.3)	163 (60.0)	1322 (65.8)
≥4	42 (36.7)	111 (40.0)	680 (34.2)
Maternal education			
None	40 (36.4)	116 (42.0)	751 (38.3)
Primary	41 (33.7)	84 (30.6)	618 (29.0)
Secondary or higher	34 (29.9)	74 (27.4)	633 (32.7)
Wealth index			
Poorest quintile	24 (19.6)	71 (23.5)	428 (19.6)
Second quintile	24 (21.6)	63 (24.0)	394 (19.8)
Middle quintile	24 (19.5)	57 (22.2)	389 (19.4)
Fourth quintile	20 (20.2)	35 (13.5)	388 (20.7)
Richest quintile	23 (19.1)	48 (16.8)	403 (20.5)
Employment status			
Currently working	34 (32.1)	70 (28.0)	339 (18.0)
Not working	81 (67.9)	204 (72.0)	1663 (82.0)
Area of residence			
Urban	35 (20.8)	81 (19.0)	557 (20.1)
Rural	80 (79.2)	193 (81.0)	1445 (79.9)
Maternal BMI			
Underweight	27 (23.1)	83 (29.3)	711 (35.3)
Average	67 (59.2)	156 (58.4)	1069 (54.5)
Overweight	16 (13.1)	26 (9.3)	169 (7.9)
Obese	5 (4.6)	9 (3.0)	53 (2.3)
Maternal desire of			

pregnancy			
Yes	77 (63.3)	171 (63.5)	1205 (60.1)
No	38 (36.7)	103 (36.5)	797 (39.9)
Ever use of contraception			
Yes	81 (72.9)	196 (71.9)	1605 (81.1)
No	34 (27.1)	78 (28.1)	397 (18.9)
No. of ANC visits			
None	48 (43.1)	146 (55.2)	998 (51.4)
1-3 visits	46 (40.7)	90 (32.0)	683 (33.7)
≥4 visits	21 (16.2)	38 (12.8)	321 (14.9)
ANC by SBA			
Yes	56 (47.3)	111 (38.6)	817 (38.8)
No	59 (52.7)	163 (61.4)	1185 (61.2)
History of any previous pregnancy loss			
Yes	35 (26.3)	79 (26.2)	435 (21.4)
No	80 (73.7)	195 (73.8)	1567 (78.6)
Sex of infant			
Male	74 (64.1)	162 (58.0)	943 (44.9)
Female	41 (35.9)	112 (42.0)	1059 (55.1)
Region			
Barisal	10 (4.2)	28 (5.5)	176 (4.7)
Chittagong	12 (10.1)	40 (13.9)	463 (25.4)
Khulna	10 (8.2)	27 (9.0)	232 (8.6)
Rajshahi	27 (25.1)	50 (20.9)	227 (13.2)
Rangpur	15 (8.0)	47 (10.7)	235 (8.2)
Sylhet	10 (3.5)	18 (3.5)	281 (7.1)
Dhaka	31 (40.9)	64 (36.5)	388 (32.8)
Year of survey			
1996	16 (14.0)	45 (15.8)	-
1999	13 (10.7)	45 (15.8)	705 (34.2)
2004	22 (20.1)	55 (21.2)	-
2007	19 (17.9)	37 (13.6)	-
2011	29 (24.1)	59 (21.5)	813 (40.1)
2014	16 (13.2)	33 (12.1)	484 (25.7)

Table 2: Results of multivariable analysis for the association between preceding birth intervals and adverse pregnancy outcomes in Bangladesh: BDHS 1996-2014

Predictors	First-day neonatal mortality N=21,382		Early neonatal mortality N=21,382		Small birth size N=11,022	
	aOR (95% CI)	P value	aOR (95% CI)	P value	aOR (95% CI)	P value
Preceding birth interval in months						
<36 months	2.11 (1.17, 3.78)	<0.05	1.58 (1.13, 2.22)	<0.05	1.04 (0.90, 1.20)	0.08
36-59 months	Reference		Reference		Reference	
≥60 months	2.02 (1.10, 3.73)		1.23 (0.84, 1.81)		1.17 (1.02, 1.34)	
Mother's age at childbirth						
≤19 years	2.51 (1.35, 4.66)	<0.05	1.53 (1.02, 2.28)	<0.05	1.01 (0.83, 1.21)	0.68
20-34 years	Reference		Reference		Reference	
≥35 years	1.34 (0.67, 2.69)		1.46 (0.93, 2.29)		1.10 (0.89, 1.36)	
Birth order						
2-3	Reference		Reference		Reference	
≥4	1.48 (0.88, 2.50)	0.14	1.27 (0.92, 1.75)	0.15	1.02 (0.89, 1.16)	0.81
Maternal education						
None	0.97 (0.49, 1.94)	0.80	0.94 (0.60, 1.46)	0.94	1.09 (0.91, 1.30)	0.05
Primary	1.15 (0.62, 2.11)		0.98 (0.65, 1.50)		0.91 (0.77, 1.07)	
Secondary or higher	Reference		Reference		Reference	
Wealth status						
Poorest quintile	0.76 (0.34, 1.68)	0.89	0.86 (0.53, 1.40)	0.68	1.30 (1.05, 1.61)	<0.05
Second quintile	0.92 (0.43, 1.95)		0.99 (0.61, 1.63)		1.34 (1.09, 1.64)	
Middle quintile	0.97 (0.48, 1.96)		1.09 (0.70, 1.72)		1.12 (0.91, 1.37)	
Fourth quintile	1.15 (0.58, 2.28)		0.80 (0.48, 1.32)		1.12 (0.93, 1.37)	

Richest quintile	Reference		Reference		Reference	
Employment status						
Currently working	1.59 (0.99, 2.56)	0.05	1.30 (0.96, 1.75)	0.09	1.02 (0.87, 1.19)	0.83
Not working	Reference		Reference		Reference	
Area of residence						
Urban	1.10 (0.64, 1.88)	0.72	1.14 (0.80, 1.63)	0.46	1.09 (0.93, 1.27)	0.28
Rural	Reference		Reference		Reference	
Maternal BMI						
Underweight	0.58 (0.35, 0.97)	<0.05	0.70 (0.52, 0.94)	0.05	1.19 (1.05, 1.34)	<0.05
Average	Reference		Reference		Reference	
Overweight	1.81 (0.90, 3.65)		1.36 (0.80, 2.32)		0.86 (0.70, 1.07)	
Obese	1.84 (0.59, 5.67)		1.23 (0.53, 2.89)		0.86 (0.60, 1.23)	
Maternal desire of pregnancy						
Yes	1.09 (0.71, 1.68)	0.68	1.13 (0.84, 1.51)	0.43	0.92 (0.81, 1.05)	0.22
No	Reference		Reference		Reference	
Ever use of contraception						
Yes	Reference		Reference		Reference	
No	2.20 (1.32, 3.68)	<0.05	1.89 (1.35, 2.64)	<0.001	1.23 (1.06, 1.42)	<0.05
No of ANC visits						
None	0.89 (0.29, 2.73)	0.62	1.61 (0.74, 3.48)	0.48	1.09 (0.84, 1.42)	0.79
1-3 visits	1.21 (0.61, 2.37)		1.16 (0.71, 1.89)		1.03 (0.86, 1.23)	
≥4 visits	Reference		Reference		Reference	
ANC by SBA						
Yes	Reference		Reference		Reference	

No	1.01 (0.46, 2.19)	0.99	0.78 (0.43, 1.42)	0.42	1.05 (0.83, 1.32)	0.70
History of any previous pregnancy loss						
Yes	1.31 (0.85, 2.03)	0.22	1.27 (0.94, 1.71)	0.12	1.04 (0.91, 1.20)	0.53
No	Reference		Reference		Reference	
Sex of infant						
Male	1.70 (1.09, 2.64)	<0.05	1.32 (1.01, 1.73)	<0.05	0.71 (0.63, 0.80)	<0.001
Female	Reference		Reference		Reference	
Region						
Barisal	0.59 (0.27, 1.30)	<0.05	0.82 (0.51, 1.30)	<0.05	0.74 (0.59, 0.92)	<0.001
Chittagong	0.34 (0.16, 0.71)		0.50 (0.32, 0.77)		1.16 (0.97, 1.38)	
Khulna	0.72 (0.35, 1.50)		0.91 (0.57, 1.44)		0.96 (0.79, 1.17)	
Rajshahi	1.12 (0.63, 1.99)		1.02 (0.68, 1.53)		0.73 (0.60, 0.89)	
Rangpur	0.68 (0.35, 1.29)		0.99 (0.66, 1.51)		0.81 (0.65, 0.99)	
Sylhet	0.83 (0.36, 1.88)		0.92 (0.53, 1.61)		1.24 (1.03, 1.50)	
Dhaka	Reference		Reference		Reference	

*Odds ratios were adjusted for maternal age at childbirth, birth order, maternal education, maternal wealth index, maternal employment status, area of residence, maternal BMI, maternal desire of pregnancy, ever use of contraceptive method, number of ANC visits, ANC by SBA, history of any previous pregnancy loss, sex of infant and region

Table 3: Results of multivariable analysis for the association between preceding birth intervals and adverse pregnancy outcomes by history of any previous pregnancy loss: BDHS 1996-2014

Predictors	First-day neonatal mortality N=21,382		Early neonatal mortality N=21,382		Small birth size N=11,022	
	aOR (95% CI)	P value	aOR (95% CI)	P value	aOR (95% CI)	P value
Preceding birth interval in months*history of any previous pregnancy loss						
<36 months	2.12 (0.74, 6.13)	0.28	1.77 (0.90, 3.49)	0.19	0.96 (0.69, 1.33)	0.38
36-59 months	Reference		Reference		Reference	
≥60 months	2.15 (0.73, 6.31)		1.74 (0.84, 3.62)		1.18 (0.87, 1.59)	

*Odds ratios were adjusted for maternal age at childbirth, birth order, maternal education, maternal wealth index, maternal employment status, area of residence, maternal BMI, maternal desire of pregnancy, ever use of contraceptive method, number of ANC visits, ANC by SBA, sex of infant and region

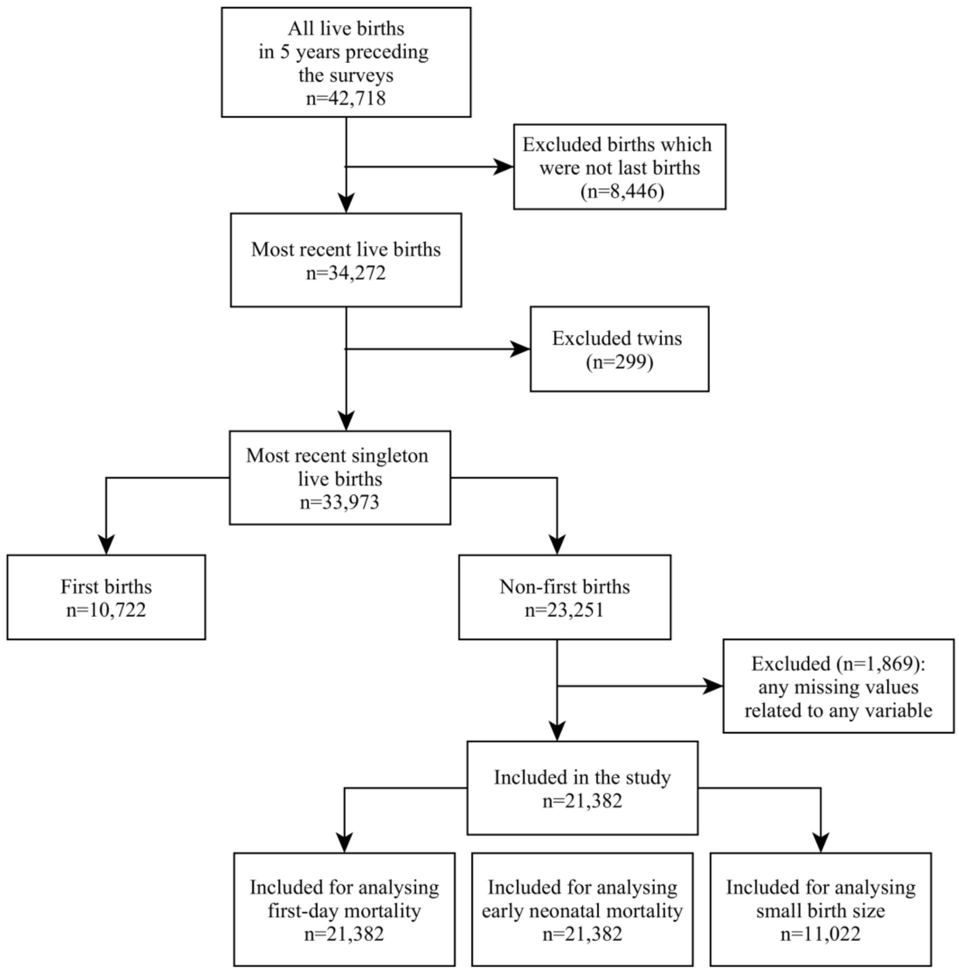

Figure 1: Flow diagram showing sample selection for first-day neonatal mortality, early neonatal mortality and small birth size analysis

203x205mm (300 x 300 DPI)

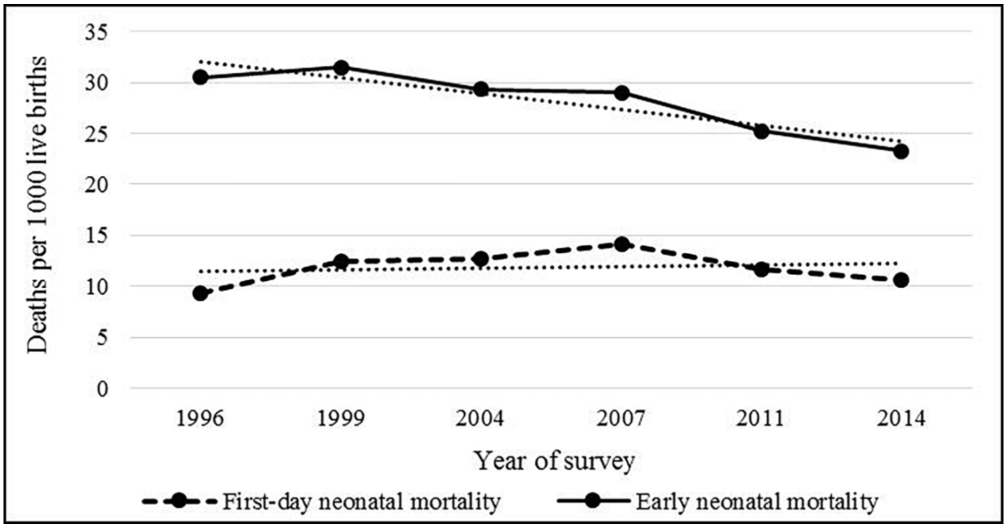

Figure 2: Trends in first-day and early neonatal mortality by year of survey (1996-2014)

191x99mm (300 x 300 DPI)

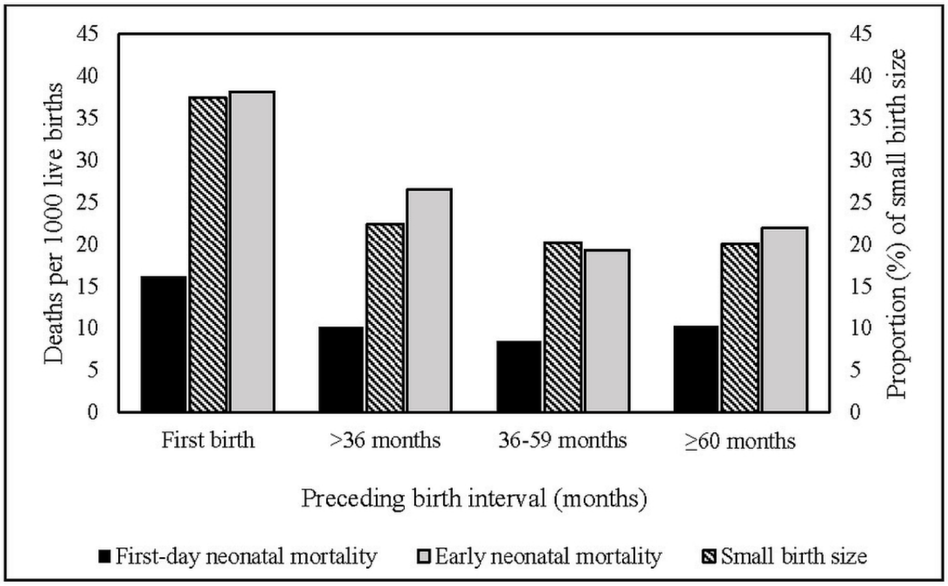

Figure 3: First-day neonatal mortality, early neonatal mortality rates per 1000 live births and the proportion of small birth size by preceding birth intervals

149x101mm (300 x 300 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***:
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	Item No	Recommendation	Reported on page no.
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 2, line 31
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2, line 30-38, 41-49
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 4-5, line 71-99
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 5, line 99-104
Methods			
Study design	4	Present key elements of study design early in the paper	Page 5-6, line 107-124
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 5-6, line 107-124
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	Page 6, line 122-124
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 6-7, line 125-160
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 6, line 125-135
Bias	9	Describe any efforts to address potential sources of bias	Page 6, line 122-124
Study size	10	Explain how the study size was arrived at	Page 5-6, line 107-124, Figure 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 7-8, line 162-186
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 7-8, line 162-187
		(*b*) Describe any methods used to examine subgroups and interactions	Page 8, line 181-183
		(*c*) Explain how missing data were addressed	Figure 1
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	Page 8, line 181-183
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing	Figure 1, Page 9, line 197-215

		follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	Page 9, line 206-212
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1, Page 10-11, line 219-243
		(b) Indicate number of participants with missing data for each variable of interest	Figure 1
Outcome data	15*	Report numbers of outcome events or summary measures	Table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2
		(*b*) Report category boundaries when continuous variables were categorized	Page 7, line 144-146, 150
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Table 3
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 12, line 269-276
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 15, line 348-371
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 12-15, line 269-341
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 16, line 373-379
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	N/A

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Risk of adverse pregnancy outcomes associated with short and long birth intervals in Bangladesh: evidence from six Bangladesh Demographic and Health Surveys, 1996-2014

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Risk of adverse pregnancy outcomes associated with short and long birth intervals in Bangladesh: evidence from six Bangladesh Demographic and Health Surveys, 1996-2014

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ABSTRACT

Objective

To examine the effect of short (<36 months) and long (≥60 months) birth intervals on adverse pregnancy outcomes in Bangladesh.

Design, setting and participants

We analysed data from six Bangladesh Demographic and Health Surveys (1996-1997, 1999-2000, 2004, 2007, 2011 and 2014). We included all singleton non-first live births, most recently born to mothers within five years preceding each survey (n=21,382). We defined birth interval according to previous research which suggests that a birth interval between 36 and 59 months is the most ideal interval. Bivariate and multivariable analyses were conducted to obtain the crude and adjusted odds ratios (aOR) respectively to assess the odds of first-day neonatal death, early neonatal death and small birth size for both short (<36 months) and long (≥60 months) spacing between births.

Main outcome measures

First-day neonatal death, early neonatal death and small birth size.

Results

In the multivariable analysis, compared to births spaced 36-59 months, infants with a birth interval of less than 36 months had increased odds of first-day neonatal death (aOR: 2.11, 95% CI: 1.17, 3.78) and early neonatal death (aOR: 1.58, 95% CI: 1.13, 2.22). Compared to births spaced 36-59 months, infants with a birth interval of ≥60 months, had increased odds of first-day neonatal death (aOR: 2.02, 95% CI: 1.10, 3.73) and small birth size (aOR: 1.17, 95% CI: 1.02, 1.34). When there was a history of any previous pregnancy loss, there was an increase in the odds of first-day and early neonatal death for both short and long birth intervals, although it was not significant.

Conclusions

Birth intervals shorter than 36 months and longer than 59 months are associated with increased odds of adverse pregnancy outcomes. Care-providers, program managers and policymakers could focus on promoting an optimal birth interval between 36-59 months in postpartum family planning.

Key words: Pregnancy outcome, birth interval, first-day neonatal death, early neonatal death, small birth size, Bangladesh

Strengths and limitations of this study

- The main strength of this study is the use of a large sample from six nationally representative surveys of Bangladesh with a very high response (98%).
- We used data from most recent births within the 5 years preceding the surveys in order to minimise recall bias.
- Our study is the first in Bangladesh which analysed the effect of birth intervals and other risk factors for first-day neonatal mortality.
- Demographic and Health Survey data is cross-sectional, which reduces the ability to infer causation.
- Demographic and Health Survey data uses maternal perceptions of infant birth size as a proxy for birthweight which may be a limitation.

BACKGROUND

Adverse pregnancy outcomes such as stillbirth, early neonatal mortality and low birthweight are of considerable public health significance. Globally, perinatal mortality (stillbirth and early neonatal mortality) accounts for more than 6 million deaths every year. Of those deaths, approximately 2 million occur in the early neonatal period.[1] The risk is greatest on the first day of life, approximately 1 million newborns die within the first 24 hours.[1] Further, low birthweight, occurs in more than 20 million newborns worldwide, which is a major contributor to perinatal mortality and up to 80% of neonatal mortality.[2] The greatest proportion of perinatal deaths and low birthweight (97-99%) occur in Low and Middle-Income Countries (LMICs).[3]

Several interventions have been suggested to address adverse pregnancy outcomes, such as pregnancy spacing.[4] Both short and long birth intervals have been reported to be associated with an increased risk of a number of adverse perinatal outcomes.[5 6] Current World Health Organization (WHO) guidelines recommend an interval of at least 24 months before attempting the next pregnancy after a live birth (i.e. birth-to-pregnancy interval) in order to reduce any adverse pregnancy outcomes.[7] Thus, the birth-to-birth interval should be at least 33 months by including nine months of pregnancy to the recommended 24 months.[8] In an analysis of Demographic and Health Survey data from 17 developing countries, Rutstein suggested that the optimal birth interval should be between 36 and 59 months as birth intervals less than 36 and more than 59 months showed a tendency towards neonatal mortality and morbidity.[9] The WHO highlighted the necessity of future research investigating the association between birth interval and adverse pregnancy outcomes.[7]

Bangladesh has a high perinatal mortality (44 per 1000 pregnancies) and morbidity,[10] where birth spacing remains a problem.[11] Between the year 1993 and 2014, though the median birth interval increased by 49% (from 35 months to 52 months), approximately 30% of non-first births occurred within less than 36 months (7 months to 35 months) following the previous birth.[10] However, another 40% of non-first births occurred following a birth interval of more than 59 months.[10] Of the papers investigating birth interval in Bangladesh, most have focussed on the effect of a short birth interval and have not considered a long birth interval as a risk of adverse perinatal outcome.[12 13] Given the changing demographics in Bangladesh and an increase in the proportion of longer birth intervals, our objective was to examine whether the preceding birth interval (short or long) was independently associated with an increased risk of adverse pregnancy outcomes including first-day neonatal mortality, early neonatal mortality and low birthweight, using pooled data from the Bangladesh Demographic and Health Surveys (BDHS).

METHODS

Data source

We used the BDHS data from the years; 1996-1997, 1999-2000, 2004, 2007, 2011 and 2014. BDHS is a nationally representative household survey carried out every three to four years under the authority of the National Institute of Population Research and Training of the Ministry of Health and Family Welfare. The survey employed a two-stage stratified cluster-sampling design with rural and urban samples to collect information from ever-married women aged 15-49 years and ever-married men 15-54 years about demographic and health status. Data were obtained from the website; www.measuredhs.com. The BDHS consists of three types of questionnaires: household, women, and men. Our analysis was limited to the information obtained from the women's and household questionnaires. We pooled the data files from six surveys and analysed the live births occurring during the five years preceding the surveys. The Demographic and Health Survey program employs standardised data collection procedures with model questionnaires to ensure consistent content over time and across countries allowing comparability across populations cross-sectionally and over time.[14] We selected six recent surveys in this pooled analysis based on the similarities in sampling design, comparability of survey questionnaires for focus variables of this analysis, and availability of data for the pooled analysis. In our analysis, we included the data from all singleton, non-first, most recent live-born children within the five years preceding the six BDHSs, 1996-1997, 1999-2000, 2004, 2007, 2011 and 2014.

Outcome variables

We conducted three analyses, with three different outcome variables - 'first-day neonatal death', 'early neonatal death' and 'small birth size'. First-day deaths were defined as deaths during the first 24 hours after birth (day 0) among live-born children, and early neonatal deaths were deaths between the age of 0 to 6 days among live-born children. These two outcome variables overlap, but conform to standard definitions. We used 'small birth size' as a proxy for low birthweight. Estimates of birthweight are not collected by the BDHS. 'Mother's perception of the infant's birth size is routinely used as a proxy indicator of birthweight. For our analysis, we defined 'small birth size' as the birth size of an infant which was perceived as either 'very small' or 'smaller than average'. Each of the outcome variables was considered dichotomous for this analysis as yes (1) or no (0).

Exposure variable

The main exposure variable used in our analysis was the length of the preceding birth interval as a measure of birth spacing. This was measured as the number of months between two successive live births.[9 15] We followed Rutstein's recommendation regarding optimal birth interval of 36-59 months for our analysis.[9] We categorised the preceding birth interval in months as short (<36 months) or long (≥ 60 months) birth intervals for our analysis; where the birth interval of 36–59 months was the reference category.

Covariates

143 Covariates included maternal age at childbirth (19 years or below, 20-34 years and 35 years or more), maternal education (none, primary and secondary or higher), birth order (2-3, ≥4), maternal Body Mass Index (BMI) (underweight, average, overweight and obese), area of residence (urban and rural), wealth index (poorest quintile, second quintile, middle quintile, fourth quintile and richest quintile), maternal employment status during survey (currently working and not working), maternal desire of pregnancy (yes and no), ever use of contraception (yes and no), number of Antenatal Care (ANC) visits (none, 1-3 visits and ≥4 visits), ANC by Skilled Birth Attendants (SBA) (yes and no), history of any previous loss of pregnancy (yes and no), sex of baby (female and male) and region (Dhaka, Barisal, Chittagong, Khulna, Rajshahi, Rangpur and Sylhet).

153 We constructed the 'wealth index' variable using principle component analysis through ranking the available wealth variables in the pooled BDHS dataset such as housing materials, type of toilet facility, source of drinking water, type of cooking fuel, availability of electricity, ownership of assets (radio, television, fridge etc.), adjusted for urban-rural differences. We constructed the 'ever use of contraception' variable from calendar data of women's dataset for each year, where 'ever use of contraception' was recorded if there was any contraceptive practice at anytime.

160 **Data analysis**

161 The 'first-day neonatal mortality' and 'early neonatal mortality' variables were calculated from the birth history data, where age at death was recorded in days if they were less than 30 days old. 'Small birth size' was calculated from the birth history data, based on the perceptions of mothers about their infant's birth size. Frequencies with weighted percentage were calculated for the selected variables to describe the characteristics of the women who had a 'first-day neonatal death', an 'early neonatal death' and a 'small birth size' infant. We conducted bivariate analysis to ascertain the unadjusted association between each of the independent

variables and each outcome separately, and multivariable analysis was performed to obtain the adjusted odds ratio (aOR). All covariates associated with the outcomes at $p \leq 0.25$ in the unadjusted analysis were included in the final multivariable logistic regression model. Further, several other covariates (maternal education, maternal wealth status, maternal area of residence, maternal desire of pregnancy, number of ANC and ANC by SBA) were included in the final model regardless of their significant levels because they are known risk factors of adverse pregnancy outcomes.[9,16,17,18] The 'year of survey' was not included in our final model as the p-value between 'year of survey' and each of the outcome variables was more than 0.25 in the unadjusted analysis. However, to test the effect of 'year of survey' we repeated the model and included 'year of survey'. This made no difference to the findings (results not shown), and hence, we kept the original model. We also checked the variables for multicollinearity. The Wald test was used to assess statistical significance with a 95% confidence interval (CI). The association was adjusted for potential confounders including maternal age at childbirth, birth order, maternal education, maternal wealth index, maternal employment status, area of residence, maternal BMI, maternal desire of pregnancy, ever use of contraceptive method, number of ANC visits, ANC by SBA, history of any previous pregnancy loss, sex of infant and region.

We further restricted our analysis by 'history of any previous pregnancy loss' to assess the combined effect of history of any previous pregnancy loss and birth interval (short or long) on all three outcomes. We followed the direct life table approach to calculate first-day and early neonatal mortality rates per 1000 live births. All analyses were carried out using STATA version 14.2. We used the 'svy' command in all our analyses to calculate the weighted values in order to adjust for the clustering effect and sample stratification.

We obtained permission from Monitoring and Evaluation to Assess and Use Results Demographic and Health Surveys (MEASURE DHS) to download the data from the DHS online archive. Ethics approval was not required for our analyses, as the data were anonymous and publicly available.

Patient involvement

No patients were involved in this study.

Figure 1: Flow diagram showing sample selection for first-day neonatal mortality, early neonatal mortality and small birth size analysis

RESULTS

Over the six surveys, and approximately 18 years of data, a total of 42,718 live births were recorded who were born to mothers aged 15-49 years within the five years preceding the surveys with a high response (approximately 98%) (Figure 1). From the years 1996 to 2014, there was a substantial decrease in the rate of overall early neonatal mortality (30.5 vs. 23.3 deaths per 1000 live births), but in terms of first-day neonatal mortality, we did not find any consistent decrease, rather the rate has increased from 9.3 deaths in 1996 to 10.6 deaths in 2014 per 1000 live births (Figure 2). Rates of all three adverse pregnancy outcomes were highest among the first-born infants followed by the infants whose births were spaced less than 36 months (Figure 3).

There were 33, 973 singleton live-born infants, most recently born to mothers within the five years preceding each survey. Of those, 10,722 (32%) were first-born infants who were ineligible as there was no birth interval, which left 21,382 non-first singleton live-born infants in our final analysis for first-day and early neonatal mortality. For small birth size, our analysis consisted of 11,022 singleton live-born infants only, for the years 1999-2000, 2011 and 2014, as the data regarding birth size were not available for the surveys in 1996-1997, 2004 and 2007 (Figure 1).

Of the 21,382 non-first singleton most recently live-born infants of six surveys, there were 115 first-day and 274 early neonatal deaths. Of 11,022 non-first singleton most recently live-born infants of three surveys, there were 2,002 infants with a birth size smaller than average.

Figure 2: Trends in first-day and early neonatal mortality by year of survey (1996-2014)

Figure 3: First-day neonatal mortality, early neonatal mortality rates per 1000 live births and the proportion of small birth size by preceding birth intervals

First-day neonatal mortality

Nearly half of the infants who died on the first-day (n=49) were born following a short birth interval, another 44 infants who died on day '0' (36.0%) were born following a long birth interval. Overall, a greater proportion of mothers of the infants who died on day '0' aged between 20-34 years (n=82, 67.5%), did not have any formal education (n=40, 36.4%), had a parity 2-3 (n=73, 63.3%), had an average BMI (n=67, 59.2%) and lived in a rural area (n=80, 79.2%) (Table 1).

Early neonatal mortality

A large proportion of deaths in the early neonatal period were attributable to day '0' deaths (n=115, 42.8%). Approximately 45% of infants (n=122) who died within 7 days of birth were born following a short birth interval. Further, a relatively higher proportion (29% vs. 26%) of early neonatal deaths had a long birth interval compared to the recommended birth interval (36-59 months). The socio-demographic characteristics of mothers of the infants who died in the early neonatal period were quite similar to the day '0' findings, and the proportion of early neonatal mortality was highest among infants born to mothers aged 20-34 years (n=200, 71.5%), had a parity 2-3 (n=163, 60.0%), did not have any formal education (n=116, 42.0%), lived in a rural area (n=193, 81.0%), had an average BMI (n=156, 58.4%) and did not receive any ANC (n=146, 55.2%) (Table 1).

Small birth size

More than one-third of infants with a small birth size (n=698, 34.6%) were born with a short birth interval. A similar proportion of infants with a small birth size (n=694, 34.2%) were born with a long birth interval. The highest proportion of infants with a small birth size were born to mothers aged 20-34 years (n=1,599, 80.0%), had a parity 2-3 (n=1,322, 65.8%), had no formal education (n=751, 38.3%), had an average BMI (n=1,069, 54.5%), lived in a rural area (n=1,445, 79.9%) and did not receive any ANC (n=998, 51.4%) (Table 1).

Association of birth intervals with first-day neonatal mortality

In the multivariable analysis, both short and long birth intervals were associated with increased odds of first-day neonatal death. Compared to infants born following a birth interval of 36-59 months, infants with a short birth interval were 2.11 times more likely to die within 24 hours of life (95% CI: 1.17, 3.78). We also found that infants born after a long birth interval, compared to those born following a birth interval of 36-59 months had 2 times higher odds of dying within 24 hours of life (95% CI: 1.10, 3.73) (Table 2).

Association of birth intervals with early neonatal mortality

After adjustment for potential confounders, early neonatal mortality was associated with a short birth interval, while for long birth intervals, no significant association was found. Compared to infants with a birth interval of 36-59 months, infants born with a short birth interval had 1.58 times higher odds of dying within 7 days of life (95% CI: 1.13, 2.22). Though the odds of early neonatal mortality were greater for long birth intervals compared to the reference group, there was no significant association (aOR: 1.23, 95% CI: 0.84, 1.81) (Table 2).

Association of birth intervals with small birth size

262 Long birth intervals appeared to be associated with increased odds of small birth size compared to the reference birth interval (aOR: 1.17, 95% CI: 1.02, 1.34), while for short birth intervals, the odds of small birth size were smaller (aOR: 1.04, 95% CI: 0.90, 1.20) compared to the reference birth interval (Table 2).

266 A history of pregnancy loss can be a determinant of birth interval and we therefore restricted our analysis to the infants whose mothers had a history of any previous pregnancy loss for all three outcomes. However, we found no significant relationship for either short or long birth intervals with all three outcomes, though for both short and long birth intervals, there was an increase in the odds for first-day and early neonatal death (Table 3).

DISCUSSION

This study suggests that both short and long birth intervals were associated with adverse pregnancy outcomes. Over the six surveys, a major proportion of infants who died on the first-day, or in the first week or with a small birth size were born before the recommended optimal birth interval (36–59 months). We found that a birth-to-birth interval shorter than 36 months was associated with increased odds of multiple adverse pregnancy outcomes including first-day neonatal mortality and early neonatal mortality. Also, a birth-to-birth interval longer than 59 months was associated with increased odds of first-day neonatal mortality and small birth size.

Infants born with a short birth-to-birth interval of less than 36 months had higher odds of first-day neonatal mortality. Several studies have reported an association of a short birth interval with perinatal or neonatal mortality.[19 20] However, to the best of our knowledge, no prior research has examined the effect of birth interval on first-day neonatal mortality individually. Further, we found that the odds of early neonatal mortality were also greater among infants who were born following a short birth interval. This is consistent with the findings of previous investigations from other LMICs which examined the effect of short birth intervals on perinatal, early neonatal or neonatal mortality.[19 20] Similar to our findings, a previous study conducted in India reported an association of neonatal death with a birth interval of less than 36 months (aOR: 1.78, 95% CI: 1.63, 1.94), compared to births spaced 36–59 months.[20] Again, an analysis of 47 Demographic Health Surveys also supports our finding of higher odds of early neonatal mortality for short birth intervals, although this analysis has used slightly different definitions of both the short birth interval (<24 months) and the reference category (24-<60 months).[21] Further, our finding is in line with the finding of a previous study conducted in Matlab, Bangladesh, where they reported an increased risk of very short birth intervals (less than 15 months) on early neonatal mortality compared to those born after 36-59 months, though in their study the risk of early neonatal mortality goes down as the birth interval increases up to a minimum of 24-59 months, which is not consistent with our findings.[12] Further, we did not find any significant association between short birth interval and small birth size, although infants born following a short interval were at increased odds of being born with a small birth size. In BDHS, birthweight is not routinely collected and birth size is based on maternal perceptions of infant birth size which could lead to errors in the estimation of small birth size and may be responsible for this non-association. However, the direction of the effect is consistent with several earlier investigations including a meta-analysis of 69 studies from both developing and developed countries.[4 19 22]

Several hypotheses have been proposed to explain the association between short birth intervals and adverse pregnancy outcomes.[23] One of the most frequently used hypotheses is the maternal nutritional depletion phenomenon, which has been defined by Winkvist et al. as a negative change in maternal nutritional status during a reproductive cycle, mostly due to the biological competition between mother and the growing fetus.[24-26] Short birth spacing does not allow mothers sufficient time to restore nutritional reserves needed to support fetal growth and development during the subsequent pregnancy. This eventually causes maternal nutritional depletion that leads to the increase risk of adverse pregnancy outcomes among the births spaced after a short interval. Another explanation is that the association of short birth intervals and adverse pregnancy outcomes could be confounded by other factors including young maternal age, lower socio-economic status and lower utilisation of health services.[27 28] In our analysis, after adjusting for maternal age, socio-economic factors, and maternal characteristics as well as health service related factors, a short birth interval remained associated with first-day and early neonatal mortality which is in line with other studies from both LMICs and high income countries which controlled for similar variables.[12 15 29 30]

Our study further identified the association of a long birth interval with adverse perinatal outcomes and found that infants born after a long birth interval were at greater odds of first-day neonatal mortality. The effect of long birth intervals on early neonatal mortality was also greater but was not significant. There are only a few published studies on the effect of a long birth interval on adverse pregnancy outcomes in LMICs and the results are conflicting.[4 19 20] In contrast to our findings, a previous investigation conducted in India, examined the effect of a long birth interval for perinatal death and did not find any association,[19] and a pooled analysis of 47 Demographic Health Surveys examined the effect of a longer birth interval for neonatal mortality and found that the odds were lower for the longer preceding birth intervals (≥60 months) (OR: 0.80, 95% CI: 0.67, 0.95) compared to the birth interval of 24-<60 months.[21] The inconsistency in findings could be attributed to methodological differences in both the reference category (36-59 months vs. 24-<60 months) of the main exposure variable and the difference in the outcome variable (early neonatal mortality vs. neonatal mortality). However, our findings are consistent with a meta-analysis which reported higher odds of early neonatal mortality with a longer interval,[4] and Rutstein's study which analysed data from 17 developing countries.[9] Again, we found that a long birth interval was associated with greater odds of small birth size, similar to a few prior studies which also suggested the detrimental effect of a long birth interval on birth size.[4 19 31]

The increased odds of adverse pregnancy outcomes for long birth intervals may be due to concurrent factors such as advanced maternal age and previous history of pregnancy loss. In an earlier investigation, Zhu et al. explained the association between long birth intervals and adverse pregnancy outcomes through the gradual decline in the maternal physiological and anatomical capacities of the reproductive system, hypothesising that if a woman does not conceive for an extended time after a delivery, her physiological characteristics may return to her unprepared primigravid state.[32] Further research is needed to understand the relationship.

Strengths and limitations

The main strength of our study is that it was based on a large nationally representative sample from six surveys within an 18-year time period in a single country which would improve the homogeneity of the data. We restricted our analysis to the most recent live births within the five years prior to the interview date to minimise recall bias. Furthermore, we were able to add a number of potential confounding factors.

We acknowledge some methodological limitations. First, this is cross-sectional data, which may limit the identification of a causal relationship between the birth interval and adverse pregnancy outcomes. Secondly, BDHS data relies on maternal recall and report of the information regarding preceding birth intervals and the days of infant deaths, which are subject to recall bias. Third, there is a possibility of underreporting of infant deaths, as birth histories and infant survival information were only collected from surviving mothers and there is a strong association between maternal and infant deaths. Fourth, we acknowledge a limitation of using maternal perception on infant birth size instead of infant birthweight in our analysis due to unavailability of actual estimates of birthweight in BDHS, which may reflect newborn's overall health status rather than birthweight only. Fifth, as we pooled six BDHS datasets over 18 years, there may be a possibility of changes in the background characteristics of the population over 18 years. Furthermore, in our analysis, we were unable to include the variable regarding the history of immediate previous adverse outcome such as stillbirth, miscarriage etc. which is a determinant of adverse perinatal outcomes in a subsequent pregnancy. A previous investigation conducted in Bangladesh using dynamic panel data models, reported that a previous adverse birth outcome may be subject to a 'scarring effect' which leads to a short birth interval (replacement) and thus increases the risk of mortality of the subsequent infant (nutritional depletion); as a mother with a previous pregnancy loss may rush into a pregnancy without properly recovering from the pregnancy loss.[33] In our analysis, we were unable to consider the role of 'scarring effect' related to a previous adverse pregnancy outcome which has an influence on birth interval. To account for this, we were able to stratify our analysis by the variable 'ever had a pregnancy loss', although that stratification increased the effect sizes of first-day and early neonatal mortality for both short and long birth intervals, neither were significant.

CONCLUSIONS

Our analysis supports the reduced risk of adverse pregnancy outcomes following a birth-to-birth interval of 36-59 months which is consistent with the WHO recommendation of a birth-to-pregnancy interval of 24 months. Our results highlight several important implications for care-providers, program managers and policymakers by suggesting that a preceding birth interval of 36-59 months could prevent adverse pregnancy outcomes including first-day neonatal death, early neonatal death and low birthweight. Promoting an optimal birth interval of 36-59 months through postpartum family planning may reduce perinatal and neonatal mortality.

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Authors' contributions

MKN, CRG and AA conceptualised and designed the study. MKN performed the literature review. MKN, CRG, MTI and TH performed statistical analysis. MKN and CRG drafted the manuscript. MKN and CRG contributed to the interpretation of the data. MKN, CRG, AA and MTI contributed to the critical revision of the manuscript. All the authors read and approved the final manuscript.

Conflict of interest

We declare that we have no conflict of interest.

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Data sharing statement

The data are anonymous and publicly available in the website; www.measuredhs.com.

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Table 1: First-day neonatal mortality, early neonatal mortality and small birth size infants by maternal characteristics in Bangladesh: BDHS 1996-2014

Predictors	First-day neonatal mortality (N= 21,382) n (%) n=115	Early neonatal mortality (N= 21,382) n (%) n=274	Small birth size (N= 11,022) n (%) n=2,002
Preceding birth interval in months			
<36 months	49 (45.2)	122 (45.2)	698 (34.6)
36-59 months	22 (18.8)	70 (26.2)	610 (31.2)
≥ 60 months	44 (36.0)	82 (28.6)	694 (34.2)
Mother's age at childbirth			
≤19 years	20 (21.1)	40 (16.2)	218 (10.7)
20-34 years	82 (67.5)	200 (71.5)	1599 (80.0)
≥35 years	13 (11.4)	34 (12.3)	185 (9.3)
Birth order			
2-3	73 (63.3)	163 (60.0)	1322 (65.8)
≥4	42 (36.7)	111 (40.0)	680 (34.2)
Maternal education			
None	40 (36.4)	116 (42.0)	751 (38.3)
Primary	41 (33.7)	84 (30.6)	618 (29.0)
Secondary or higher	34 (29.9)	74 (27.4)	633 (32.7)
Wealth index			
Poorest quintile	24 (19.6)	71 (23.5)	428 (19.6)
Second quintile	24 (21.6)	63 (24.0)	394 (19.8)
Middle quintile	24 (19.5)	57 (22.2)	389 (19.4)
Fourth quintile	20 (20.2)	35 (13.5)	388 (20.7)
Richest quintile	23 (19.1)	48 (16.8)	403 (20.5)
Employment status			
Currently working	34 (32.1)	70 (28.0)	339 (18.0)
Not working	81 (67.9)	204 (72.0)	1663 (82.0)
Area of residence			
Urban	35 (20.8)	81 (19.0)	557 (20.1)
Rural	80 (79.2)	193 (81.0)	1445 (79.9)
Maternal BMI			
Underweight	27 (23.1)	83 (29.3)	711 (35.3)
Average	67 (59.2)	156 (58.4)	1069 (54.5)
Overweight	16 (13.1)	26 (9.3)	169 (7.9)
Obese	5 (4.6)	9 (3.0)	53 (2.3)

Maternal desire of pregnancy			
Yes	77 (63.3)	171 (63.5)	1205 (60.1)
No	38 (36.7)	103 (36.5)	797 (39.9)
Ever use of contraception			
Yes	81 (72.9)	196 (71.9)	1605 (81.1)
No	34 (27.1)	78 (28.1)	397 (18.9)
No. of ANC visits			
None	48 (43.1)	146 (55.2)	998 (51.4)
1-3 visits	46 (40.7)	90 (32.0)	683 (33.7)
≥4 visits	21 (16.2)	38 (12.8)	321 (14.9)
ANC by SBA			
Yes	56 (47.3)	111 (38.6)	817 (38.8)
No	59 (52.7)	163 (61.4)	1185 (61.2)
History of any previous pregnancy loss			
Yes	35 (26.3)	79 (26.2)	435 (21.4)
No	80 (73.7)	195 (73.8)	1567 (78.6)
Sex of infant			
Male	74 (64.1)	162 (58.0)	943 (44.9)
Female	41 (35.9)	112 (42.0)	1059 (55.1)
Region			
Barisal	10 (4.2)	28 (5.5)	176 (4.7)
Chittagong	12 (10.1)	40 (13.9)	463 (25.4)
Khulna	10 (8.2)	27 (9.0)	232 (8.6)
Rajshahi	27 (25.1)	50 (20.9)	227 (13.2)
Rangpur	15 (8.0)	47 (10.7)	235 (8.2)
Sylhet	10 (3.5)	18 (3.5)	281 (7.1)
Dhaka	31 (40.9)	64 (36.5)	388 (32.8)
Year of survey			
1996	16 (14.0)	45 (15.8)	-
1999	13 (10.7)	45 (15.8)	705 (34.2)
2004	22 (20.1)	55 (21.2)	-
2007	19 (17.9)	37 (13.6)	-
2011	29 (24.1)	59 (21.5)	813 (40.1)
2014	16 (13.2)	33 (12.1)	484 (25.7)

Table 2: Results of multivariable analysis for the association between preceding birth intervals and adverse pregnancy outcomes in Bangladesh: BDHS 1996-2014

Predictors	First-day neonatal mortality N=21,382		Early neonatal mortality N=21,382		Small birth size N=11,022	
	aOR (95% CI)	p-value	aOR (95% CI)	p-value	aOR (95% CI)	p-value
Preceding birth interval in months						
<36 months	2.11 (1.17, 3.78)	<0.05	1.58 (1.13, 2.22)	<0.05	1.04 (0.90, 1.20)	0.08
36-59 months	Reference		Reference		Reference	
≥60 months	2.02 (1.10, 3.73)		1.23 (0.84, 1.81)		1.17 (1.02, 1.34)	
Mother's age at childbirth						
≤19 years	2.51 (1.35, 4.66)	<0.05	1.53 (1.02, 2.28)	<0.05	1.01 (0.83, 1.21)	0.68
20-34 years	Reference		Reference		Reference	
≥35 years	1.34 (0.67, 2.69)		1.46 (0.93, 2.29)		1.10 (0.89, 1.36)	
Birth order						
2-3	Reference		Reference		Reference	
≥4	1.48 (0.88, 2.50)	0.14	1.27 (0.92, 1.75)	0.15	1.02 (0.89, 1.16)	0.81
Maternal education						
None	0.97 (0.49, 1.94)	0.80	0.94 (0.60, 1.46)	0.94	1.09 (0.91, 1.30)	0.05
Primary	1.15 (0.62, 2.11)		0.98 (0.65, 1.50)		0.91 (0.77, 1.07)	
Secondary or higher	Reference		Reference		Reference	
Wealth status						
Poorest quintile	0.76 (0.34, 1.68)	0.89	0.86 (0.53, 1.40)	0.68	1.30 (1.05, 1.61)	<0.05
Second quintile	0.92 (0.43, 1.95)		0.99 (0.61, 1.63)		1.34 (1.09, 1.64)	
Middle quintile	0.97 (0.48, 1.96)		1.09 (0.70, 1.72)		1.12 (0.91, 1.37)	
Fourth quintile	1.15 (0.58, 2.28)		0.80 (0.48, 1.32)		1.12 (0.93, 1.37)	

Richest quintile	Reference		Reference		Reference	
Employment status						
Currently working	1.59 (0.99, 2.56)	0.05	1.30 (0.96, 1.75)	0.09	1.02 (0.87, 1.19)	0.83
Not working	Reference		Reference		Reference	
Area of residence						
Urban	1.10 (0.64, 1.88)	0.72	1.14 (0.80, 1.63)	0.46	1.09 (0.93, 1.27)	0.28
Rural	Reference		Reference		Reference	
Maternal BMI						
Underweight	0.58 (0.35, 0.97)	<0.05	0.70 (0.52, 0.94)	0.05	1.19 (1.05, 1.34)	<0.05
Average	Reference		Reference		Reference	
Overweight	1.81 (0.90, 3.65)		1.36 (0.80, 2.32)		0.86 (0.70, 1.07)	
Obese	1.84 (0.59, 5.67)		1.23 (0.53, 2.89)		0.86 (0.60, 1.23)	
Maternal desire of pregnancy						
Yes	1.09 (0.71, 1.68)	0.68	1.13 (0.84, 1.51)	0.43	0.92 (0.81, 1.05)	0.22
No	Reference		Reference		Reference	
Ever use of contraception						
Yes	Reference		Reference		Reference	
No	2.20 (1.32, 3.68)	<0.05	1.89 (1.35, 2.64)	<0.001	1.23 (1.06, 1.42)	<0.05
No of ANC visits						
None	0.89 (0.29, 2.73)	0.62	1.61 (0.74, 3.48)	0.48	1.09 (0.84, 1.42)	0.79
1-3 visits	1.21 (0.61, 2.37)		1.16 (0.71, 1.89)		1.03 (0.86, 1.23)	
≥4 visits	Reference		Reference		Reference	
ANC by SBA						
Yes	Reference		Reference		Reference	

No	1.01 (0.46, 2.19)	0.99	0.78 (0.43, 1.42)	0.42	1.05 (0.83, 1.32)	0.70
History of any previous pregnancy loss						
Yes	1.31 (0.85, 2.03)	0.22	1.27 (0.94, 1.71)	0.12	1.04 (0.91, 1.20)	0.53
No	Reference		Reference		Reference	
Sex of infant						
Male	1.70 (1.09, 2.64)	<0.05	1.32 (1.01, 1.73)	<0.05	0.71 (0.63, 0.80)	<0.001
Female	Reference		Reference		Reference	
Region						
Barisal	0.59 (0.27, 1.30)	<0.05	0.82 (0.51, 1.30)	<0.05	0.74 (0.59, 0.92)	<0.001
Chittagong	0.34 (0.16, 0.71)		0.50 (0.32, 0.77)		1.16 (0.97, 1.38)	
Khulna	0.72 (0.35, 1.50)		0.91 (0.57, 1.44)		0.96 (0.79, 1.17)	
Rajshahi	1.12 (0.63, 1.99)		1.02 (0.68, 1.53)		0.73 (0.60, 0.89)	
Rangpur	0.68 (0.35, 1.29)		0.99 (0.66, 1.51)		0.81 (0.65, 0.99)	
Sylhet	0.83 (0.36, 1.88)		0.92 (0.53, 1.61)		1.24 (1.03, 1.50)	
Dhaka	Reference		Reference		Reference	

*Odds ratios were adjusted for maternal age at childbirth, birth order, maternal education, maternal wealth index, maternal employment status, area of residence, maternal BMI, maternal desire of pregnancy, ever use of contraceptive method, number of ANC visits, ANC by SBA, history of any previous pregnancy loss, sex of infant and region

Table 3: Results of multivariable analysis for the association between preceding birth intervals and adverse pregnancy outcomes by history of any previous pregnancy loss: BDHS 1996-2014

Predictors	First-day neonatal mortality N=21,382		Early neonatal mortality N=21,382		Small birth size N=11,022	
	aOR (95% CI)	p-value	aOR (95% CI)	p-value	aOR (95% CI)	p-value
Preceding birth interval in months*history of any previous pregnancy loss						
<36 months	2.12 (0.74, 6.13)	0.28	1.77 (0.90, 3.49)	0.19	0.96 (0.69, 1.33)	0.38
36-59 months	Reference		Reference		Reference	
≥60 months	2.15 (0.73, 6.31)		1.74 (0.84, 3.62)		1.18 (0.87, 1.59)	

*Odds ratios were adjusted for maternal age at childbirth, birth order, maternal education, maternal wealth index, maternal employment status, area of residence, maternal BMI, maternal desire of pregnancy, ever use of contraceptive method, number of ANC visits, ANC by SBA, sex of infant and region

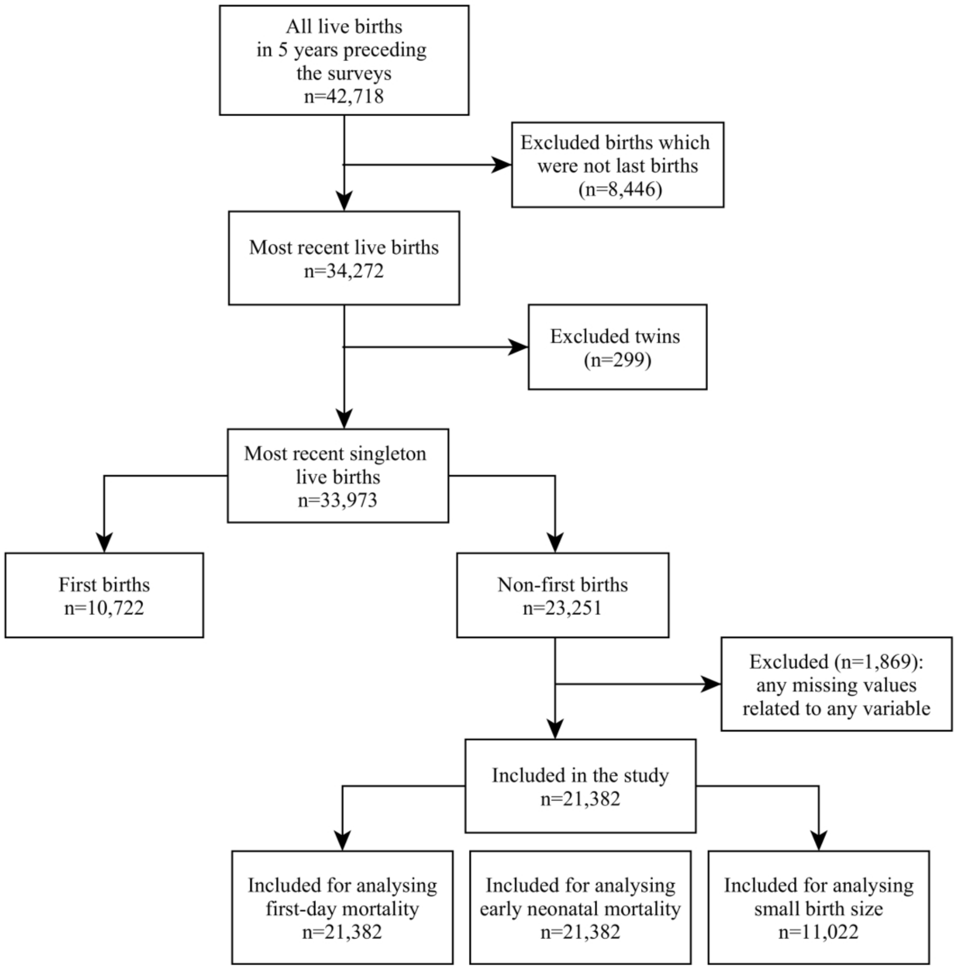

Figure 1: Flow diagram showing sample selection for first-day neonatal mortality, early neonatal mortality and small birth size analysis

203x205mm (300 x 300 DPI)

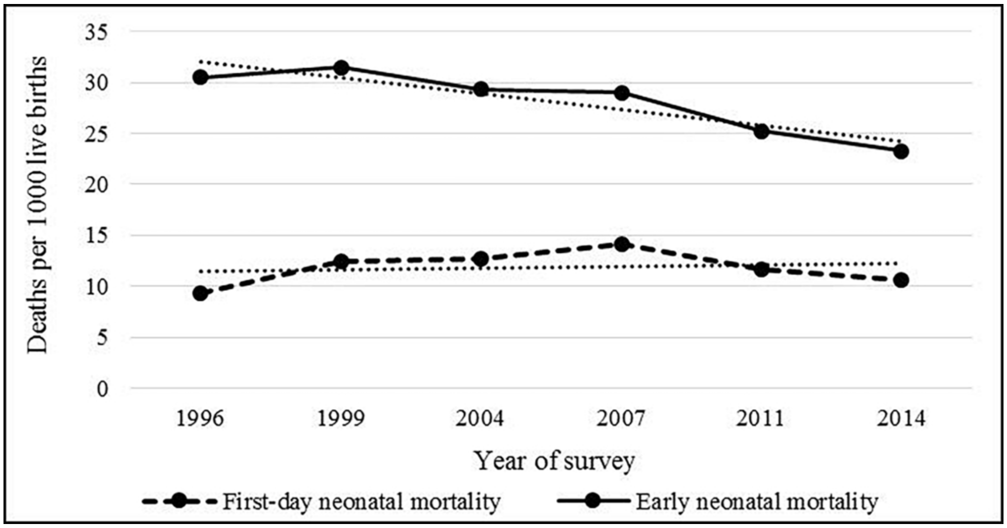

Figure 2: Trends in first-day and early neonatal mortality by year of survey (1996-2014)

191x99mm (300 x 300 DPI)

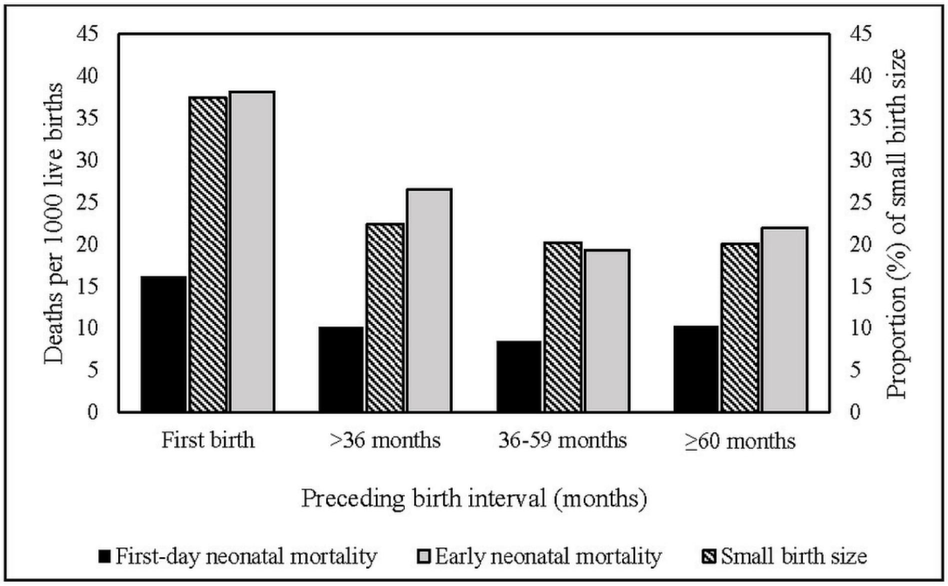

Figure 3: First-day neonatal mortality, early neonatal mortality rates per 1000 live births and the proportion of small birth size by preceding birth intervals

149x101mm (300 x 300 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***:
Manuscript ID bmjopen-2018-024392

	Item No	Recommendation	Reported on page no.
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 2, line 31
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2, line 30-38, 41-49
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 4-5, line 71-99
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 5, line 99-104
Methods			
Study design	4	Present key elements of study design early in the paper	Page 5-6, line 107-124
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 5-6, line 107-124
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	Page 6, line 122-124
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 6-7, line 125-160
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 6, line 125-135
Bias	9	Describe any efforts to address potential sources of bias	Page 6, line 122-124
Study size	10	Explain how the study size was arrived at	Page 5-6, line 107-124, Figure 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 7-8, line 162-186
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 7-8, line 162-187
		(*b*) Describe any methods used to examine subgroups and interactions	Page 8, line 181-183
		(*c*) Explain how missing data were addressed	Figure 1
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	Page 8, line 181-183
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing	Figure 1, Page 9, line 197-215

		follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	Page 9, line 206-212
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1, Page 10-11, line 219-243
		(b) Indicate number of participants with missing data for each variable of interest	Figure 1
Outcome data	15*	Report numbers of outcome events or summary measures	Table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2
		(*b*) Report category boundaries when continuous variables were categorized	Page 7, line 144-146, 150
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Table 3
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 12, line 269-276
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 15, line 348-371
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 12-15, line 269-341
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 16, line 373-379
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	N/A