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Effects of interpregnancy interval and outcome of the preceding pregnancy on pregnancy outcomes in Matlab, Bangladesh

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Objective To estimate the effects on pregnancy outcomes of the duration of the preceding interpregnancy interval (IPI) and type of pregnancy outcome that began the interval.

Design Observational population-based study.

Setting The Maternal Child Health–Family Planning (MCH–FP) area of Matlab, Bangladesh.

Population A total of 66 759 pregnancy outcomes that occurred between 1982 and 2002.

Methods Bivariate tabulations and multinomial logistic regression analysis.

Main outcome measures Pregnancy outcomes (live birth, stillbirth, miscarriage [spontaneous fetal loss prior to 28 weeks], and induced abortion).

Results When socio-economic and demographic covariates are controlled, of the IPIs that began with a live birth, those <6 months in duration were associated with a 7.5-fold increase in the odds of an induced abortion (95% CI 6.0–9.4), a 3.3-fold increase in the odds of a miscarriage (95% CI 2.8–3.9), and a 1.6-fold increase in the odds of a stillbirth (95% CI 1.2–2.1) compared with 27- to 50-month IPIs. IPIs of 6–14 months were associated with increased odds of induced abortion (2.0, 95% CI 1.5–2.6). IPIs ≥ 75 months were associated with increased odds of all three types of non-live-birth (NLB) outcomes but were not as risky as very short intervals. IPIs that began with a NLB were generally more likely to end with the same type of NLB.

Conclusions Women whose pregnancies are between 15 and 75 months after a preceding pregnancy outcome (regardless of its type) have a lower likelihood of fetal loss than those with shorter or longer IPIs. Those with a preceding NLB outcome deserve special attention in counselling and monitoring.

Keywords Birth spacing, fetal loss, induced abortion, interpregnancy intervals, miscarriage, pregnancy outcomes, pregnancy spacing, stillbirth.

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Introduction

There has been extensive research on the effects of pregnancy or birth spacing on a variety of outcomes, including infant and child mortalities,[1] child health,[2–5] maternal mortality,[6] and maternal morbidity.[7] This research has generally found that short interpregnancy intervals (IPIs) (<6 to <27 months, depending on the study) are associated with higher rates of infant and child mortalities, maternal death, third-trimester bleeding, premature rupture of membranes, puerperal endometritis, and anaemia. Some studies have also found significant deleterious effects of very long intervals (approximately >59 months depending on the study), particularly increased risks of maternal mortality, pre-eclampsia, and eclampsia. However, there have been very few studies[8–12] of whether pregnancy spacing also affects pregnancy outcomes—i.e. whether the pregnancy results in a live birth, stillbirth, miscarriage, or induced abortion. One reason for this is that it is much

more difficult to collect reliable data on pregnancies that do not result in a live birth. There have been even fewer studies of whether the effects of IPIs differ by the type of pregnancy outcome that begins the interval. Most studies have looked at interbirth or birth-to-conception intervals. An exception is Conde-Agudelo *et al.*,[13] who look at the effects of post-abortion intervals in Latin America. However, that study was unable to distinguish whether the post-abortion interval began with an induced abortion or a spontaneous miscarriage. Information about how the effects of IPIs vary by the type of outcome that began the interval can help medical practitioners better tailor the advice they give to women about how long they should wait after one pregnancy before trying to become pregnant again.

The objective of our study was to estimate the effects of the duration of the preceding IPI on pregnancy outcomes (live birth, stillbirth, spontaneous fetal loss prior to 28 weeks, and induced abortion). We also investigated whether the effects of IPI differ depending on the type of pregnancy outcome that began the interval.

Methods

This study uses data from Matlab, a typical rural subdistrict of Bangladesh, which is a poor, traditional country in South Asia. Our data on pregnancies and their outcomes have been collected through the Demographic Surveillance System (DSS) of the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B). The DSS data on the timing of pregnancy outcomes are of quite high quality because they have been collected during regular household visits (every 2 weeks until 1999 and every month since then) by trusted female community health workers (CHWs).[14,15]

Since October 1977, half of the DSS area has been exposed to the Maternal Child Health–Family Planning (MCH–FP) intervention of the ICDDR,B, which provides better family planning and health services than the standard government services available elsewhere.[15,16] Until 2000, well-trained CHWs visited married women of reproductive age in this area every 2 weeks to provide counselling about family planning services and to deliver injectables, pills, and condoms at the doorstep. (Since 2001, CHWs visit the doorstop only to collect data; they no longer deliver services, and women in the MCH–FP area must now go to a fixed-site clinic to receive the services.) In addition to the standard government health and family welfare centres, the MCH–FP area also has ICDDR,B subcentres that provide maternal and child health and family planning services.

In this study, we restrict our attention to the MCH–FP area, as only in this area has information been collected about the date of the last menstrual period, enabling measurement of the duration of the IPI. Date of last menstrual period (and hence estimated duration of pregnancy) is reported for 93.7% of pregnancies in the MCH–FP area. It is asked by the CHWs of all women on each household visit, whether or not the respondents report being pregnant. We consider data from the DSS on 66 759 pregnancies that occurred in the MCH–FP area of Matlab between 1982 and 2002. We include all pregnancies in this analysis, even those that resulted in multiple births. (We include pregnancies that resulted in multiple births because it is possible that some of the pregnancies that did not result in live births had multiple fetuses, but we did not have that information. It might bias our results if we omitted the former but included the latter.) Of the pregnancies in our sample, 1447 (2.2%) resulted in an induced abortion, 3539 (5.3%) in a spontaneous fetal loss prior to 28 weeks since the last menstrual period, 2028 (3.0%) in a stillbirth, and 59 745 (89.5%) in a live birth.

Following the literature, we measure the IPI as the number of months between the date of the outcome of the preceding pregnancy and date of the last menstrual period before the index pregnancy. There are 11 768 cases in our sample for which IPI duration is unknown. For 706 cases with an unknown IPI, we do not know the exact date of the last menstrual period; the remainder are unknown because we do not have information on the date of the preceding pregnancy outcome (other than to know that there was one), either because the preceding pregnancy occurred before the study began or before the woman entered the sample (i.e. if she migrated into the DSS area, we would only have information on her pregnancies since she has been in the area). These cases are included in our analyses as 'unknown duration of IPI'.

Our analysis includes first pregnancies ($n = 16\,870$), so that we can assess how their risks of non-live-birth (NLB) outcomes differ from those of higher-order pregnancies.

Our multivariate analyses control for variables that may affect pregnancy spacing and whether the pregnancy resulted in a live birth. These additional explanatory variables are pregnancy parity, the woman's age and education, her husband's education, household space (a proxy for the household's economic status), religion, whether the pregnancy was intended, and the calendar year and calendar month of the outcomes. Descriptive statistics for these variables and an analysis of their effects are available from the authors upon request.

The dependent variable has the following four categories: live birth (delivery of a live baby at any gestational age), stillbirth (fetal loss at 28 weeks or more since the last menstrual period), spontaneous miscarriage (spontaneous fetal loss prior to 28 weeks since the last menstrual period), and induced abortion (as coded in the data through self-report). (The 28-week distinction between spontaneous miscarriages and stillbirths is the one which ICDDR,B has used in coding the data. We will refer to the former as 'miscarriages' in this paper, even though shorter durations are typically used in

other studies.) For each of these, we first show how rates of pregnancy outcomes vary by duration of the preceding IPI (<6 months, 6–14 months, 15–26 months, 27–50 months, 51–74 months, and ≥75 months) and the outcome of the preceding pregnancy. We treat IPIs of 27–50 months as the reference category; for pregnancies that resulted in full-term live births, this corresponds to an interbirth interval of 3–5 years. We allow the effects of IPI categories less than 51 months in length to differ by whether the preceding pregnancy resulted in an induced abortion, miscarriage, stillbirth, or live birth. We do not do this with intervals beyond 51 months because there were too few pregnancies that followed NLB for longer intervals.

We also estimate a multinomial logistic regression, which shows how the interval variables affect the odds that the pregnancy ended with an induced abortion, miscarriage, or stillbirth, relative to resulting in a live birth, when our other explanatory variables are controlled. We present the results from the multinomial logistic regression analyses as adjusted odds ratios (and 95% CI). We also present, for comparison, unadjusted odds ratios from a multinomial logistic equation that does not control for the additional covariates. Using the cluster command in Stata 9.0 (Statacrop, College Station, TX, USA), all standard errors in the multivariate analyses are adjusted to account for the nonindependence of pregnancies to the same woman. (Our 66 759 pregnancies occurred to 28 540 different women.)

Results

Table 1 shows the distribution of the preceding IPIs for all pregnancies in our sample and for second-order and higher-order pregnancies in the MCH–FP area for which we have data on the date of the last menstrual period before the conception. Of pregnancies with a known IPI duration, 9.7% were preceded by an IPI of less than 6 months, 10.4% were preceded by an IPI of 6–14 months, and 6.4% occurred after an IPI of at least 75 months.

Table 2 shows, for each category of IPI duration, the distribution of pregnancy outcomes that began the interval and demonstrates that the two are not independent. Short intervals are much more likely to begin with a NLB than are longer ones. Fifty-six percent of IPIs of <6 months began with a NLB, more than 30% of IPIs of 6–14 months began with a NLB, but just 7.7% of IPIs of 15–26 months began with a NLB, and only 2.8% of IPIs of 27–50 months began with a NLB. Compared with IPIs of 27–50 months, IPIs of <6 months are 31 times more likely to begin with a miscarriage, 16 times more likely to begin with a stillbirth, and 6 times more likely to begin with an induced abortion.

Table 3 shows how the rates of induced abortion, miscarriage, stillbirth, and live birth are associated with IPIs of various lengths and the outcome of the preceding pregnancy. Each rate shown is tested against the reference category of pregnancies following live births after an IPI of 27–50 months. We also test differences across outcome-of-previous-pregnancy categories within each IPI category. Table 4 shows adjusted odds ratios, when the other covariates mentioned above are controlled, and unadjusted odds ratios. In what follows, we discuss the patterns in Table 3 but note instances where controlling for additional covariates (shown in Table 4) changes effects notably. If not so noted, adjustment for the other variables did not affect the results in a meaningful way.

Induced abortion

For each IPI category less than 51 months, the highest rates of induced abortion occur for women whose previous pregnancy ended with an induced abortion, and they are high regardless of the amount of time since the previous abortion. For pregnancies after induced abortions, the rate of subsequent induced abortion was 12.7, 7.2, 11.1, and 14.7% for IPIs of <6 months, 6–14 months, 25–26 months, and 27–50

Table 1. Distribution of IPIs (n = 66 759)

	Percentage of entire sample	Percentage of all cases with known duration of IPI
IPI (months)		
<6	5.6	9.7
6–14	6.0	10.4
15–26	13.1	22.9
27–50	21.3	37.4
51–74	7.5	13.2
≥75	3.6	6.4
Unknown	17.6	—
First pregnancy	25.3	—

Table 2. Distribution of pregnancy outcomes that began IPI according to length of IPI (for IPIs of known duration; n = 38 121)

IPI (months)	Interval began with (%)				Total
	Induced abortion	Miscarriage	Stillbirth	Live birth	
<6	4.0	36.9	14.8	44.3	100
6–14	3.5	17.6	10.3	68.7	100
15–26	1.4	3.5	2.7	92.3	100
27–50	0.7	1.2	0.9	97.2	100
51–74	0.7	1.0	0.7	97.6	100
≥75	0.7	1.2	1.0	97.1	100

Table 3. Percentage of index pregnancies ending in induced abortion, miscarriage, stillbirth, and live birth, by duration of preceding IPI and type of preceding pregnancy outcome

	Induced abortion (%)	Miscarriage (%)	Stillbirth (%)	Live birth (%)	Total (*n*)
IPI of <6 months, interval began with					
Induced abortion	12.7*	6.7**	1.3	79.3*	150
Miscarriage	1.2**	8.2*,**	3.0	87.7*,**	1366
Stillbirth	1.5**	8.0*,**	5.5*,**	85.1*,**	550
Live birth	9.2*	12.9*	3.2*	74.8*	1640
IPI of 6–14 months, interval began with					
Induced abortion	7.2*,**	5.8	5.1*,**	81.3*,**	139
Miscarriage	0.1*,**	8.4*,**	4.1*,**	87.3*,**	700
Stillbirth	0.9**	7.8*,**	8.8*,**	82.3*,**	409
Live birth	3.2*	4.1	2.9	90.2	2738
IPI of 15–26 months, interval began with					
Induced abortion	11.1*,**	2.4	4.8	81.7*,**	126
Miscarriage	1.3	7.5*,**	4.3*,**	86.9*,**	305
Stillbirth	0.8	6.7**	7.5*,**	85.0*,**	240
Live birth	1.9	4.0*	2.4	91.7	8070
IPI of 27–50 months, interval began with					
Induced abortion	14.7*,**	5.2	5.3	74.7*,**	95
Miscarriage	2.4	7.8	4.2	85.5*,**	166
Stillbirth	3.7	5.3	9.0*,**	81.8*,**	132
Live birth	1.7	5.0	2.5	90.9	13 853
IPI of 51–74 months	2.5*	5.3	2.5	89.6*	5021
IPI of ≥75 months	6.2*	7.2*	3.6*	89.2*	2421
Unknown IPI	2.3*	4.7	3.4*	89.6*	11 768
First pregnancy	1.0*	5.2	3.3*	90.5	16 870
Total sample	2.2	5.3	3.0	89.5	66 759

Because of rounding, not all percentages in each row add up to exactly 100%.
*$P < 0.05$ in a test comparing each proportion to the reference category of an IPI of 27–50 months that began with a live birth.
**$P < 0.05$ in a test comparing each proportion to the reference category of an IPI of the same duration that began with a live birth.

months, respectively. The relative odds that a pregnancy will end in an induced abortion after an interval that began with an induced abortion (compared with the reference category of IPIs of 27–50 months that began with a live birth) are smaller when our other covariates are controlled, but they are still sizable (ranging from an OR of 2.77 [95% CI 1.36–5.63] for IPI of 6–14 months to an OR of 4.99 [95% CI 2.72–9.15] for IPI of 15–26 months) (Table 4).

IPIs shorter than 6 months after live births are also associated with high rates of induced abortion (9.2%). The relative odds (compared with the IPIs of 27–50 months that began with a live birth) are even greater when other covariates are controlled (OR = 7.53; 95% CI 6.02–9.41). IPIs of 6–14 months after live births are associated with an above-average rate of induced abortion (3.2%), although to a lesser extent than those less than 6 months, and the odds ratio is somewhat higher when other covariates are controlled (OR = 1.96; 95% CI 1.50–2.55) than when they are not. Very long intervals (≥75 months) are also associated with elevated rates of induced abortion (6.2%). The relative odds are reduced considerably when other variables are controlled, but they are well over 1.0 (OR = 1.73; 95% CI 1.37–2.18).

Of IPIs of 50 months or less that began with a live birth, the lowest rates of induced abortion occur after IPIs of 15–26 months (1.9%) and 27–50 months (1.7%).

Overall, the lowest rates of induced abortion occur for IPIs of less than 26 months after miscarriages and stillbirths (0.1–1.5%). Rates of induced abortion are also low for first pregnancies (1.0%).

Miscarriage (spontaneous fetal loss prior to 28 weeks)

Rates of spontaneous fetal loss prior to 28 weeks (which we refer to as miscarriages in this study) are highest for IPIs less

Table 4. Odds ratios from multinomial logistic regression for pregnancy outcome (IPIs of 27–50 months that began with a live birth are the reference category) (n = 66 759)

	Induced abortion		Miscarriage		Stillbirth	
	Adjusted OR (95% CI)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	Unadjusted OR (95% CI)
IPI of <6 months, interval began with						
Induced abortion	4.92 (2.83–8.53)	8.48 (5.08–14.16)	1.27 (0.66–2.44)	1.54 (0.80–2.95)	0.62 (0.15–2.53)	0.62 (0.15–2.53)
Miscarriage	0.69 (0.40–1.19)	0.71 (0.41–1.22)	1.61 (1.29–2.00)	1.71 (1.39–2.12)	1.31 (0.94–1.82)	1.27 (0.91–1.76)
Stillbirth	0.98 (0.48–2.01)	0.91 (0.45–1.85)	1.80 (1.31–2.47)	1.72 (1.25–2.37)	2.35 (1.57–3.50)	2.37 (1.59–3.54)
Live birth	7.53 (6.02–9.41)	6.54 (5.28–8.10)	3.30 (2.77–3.90)	3.15 (2.68–3.72)	1.61 (1.20–2.18)	1.57 (1.17–2.12)
IPI of 6–14 months, interval began with						
Induced abortion	2.77 (1.36–5.63)	4.70 (2.45–9.03)	1.17 (0.57–2.40)	1.30 (0.63–2.67)	2.56 (1.22–5.37)	2.62 (1.27–5.42)
Miscarriage	0.08 (0.01–0.55)	0.09 (0.01–0.62)	1.80 (1.35–2.39)	1.77 (1.33–2.35)	1.76 (1.20–2.61)	1.76 (1.20–2.58)
Stillbirth	0.60 (0.23–1.61)	0.63 (0.23–1.70)	1.70 (1.16–2.49)	1.74 (1.19–2.54)	4.03 (2.74–5.92)	3.96 (2.71–5.78)
Live birth	1.96 (1.50–2.55)	1.91 (1.48–2.47)	0.81 (0.66–1.00)	0.82 (0.67–1.01)	1.00 (0.76–1.31)	0.99 (0.76–1.29)
IPI of 15–26 months, interval began with						
Induced abortion	4.99 (2.72–9.15)	7.22 (3.85–13.54)	0.48 (0.15–1.53)	0.53 (0.17–1.69)	2.13 (0.93–4.90)	2.16 (0.94–4.95)
Miscarriage	0.59 (0.21–1.62)	0.80 (0.30–2.16)	1.50 (0.97–2.33)	1.59 (1.03–2.45)	1.79 (0.98–3.27)	1.82 (1.00–3.31)
Stillbirth	0.47 (0.11–1.91)	0.52 (0.13–2.11)	1.34 (0.79–2.26)	1.44 (0.86–2.41)	3.15 (1.85–5.38)	3.27 (1.91–5.57)
Live birth	1.13 (0.91–1.40)	1.08 (0.88–1.33)	0.82 (0.71–0.94)	0.80 (0.70–0.91)	0.93 (0.77–1.12)	0.97 (0.80–1.16)
IPI of 27–50 months, interval began with						
Induced abortion	4.97 (2.61–9.45)	10.47 (5.82–18.84)	1.10 (0.45–2.74)	1.29 (0.52–3.21)	2.54 (1.02–6.32)	2.61 (1.05–6.50)
Miscarriage	1.05 (0.37–2.97)	1.50 (0.55–4.08)	1.62 (0.91–2.90)	1.68 (0.95–2.97)	1.74 (0.81–3.76)	1.83 (0.85–3.93)
Stillbirth	1.57 (0.61–4.04)	2.46 (0.99–6.08)	1.12 (0.52–2.44)	1.19 (0.55–2.56)	3.65 (1.91–6.97	4.11 (2.16–7.82)
Live birth (reference)	1.00 (—)	1.00 (—)	1.00 (—)	1.00 (—)	1.00 (—)	1.00 (—)
IPI of 51–74 months	1.11 (0.89–1.39)	1.51 (1.22–1.88)	1.00 (0.86–1.17)	1.09 (0.94–1.26)	1.03 (0.83–1.27)	1.04 (0.85–1.29)
IPI of ≥75 months	1.73 (1.37–2.18)	3.97 (3.21–4.90)	1.28 (1.06–1.54)	1.60 (1.35–1.90)	1.53 (1.19–1.98)	1.62 (1.28–2.06)
Unknown IPI	1.76 (1.41–2.18)	1.37 (1.14–1.64)	0.99 (0.85–1.13)	0.96 (0.85–1.08)	1.41 (1.17–1.69)	1.40 (1.21–1.62)
First pregnancy	0.64 (0.49–0.83)	0.58 (0.48–0.71)	0.94 (0.82–1.08)	1.06 (0.96–1.18)	1.65 (1.39–1.96)	1.35 (1.18–1.55)

CI, confidence interval; OR, odds ratio.OR = exp(β), where β is the coefficient in the multinomial logistic model. Adjusted models control for pregnancy parity, maternal age, woman's education, husband's education, household space size, religion, wantedness, month of pregnancy outcome, and year of pregnancy outcome.

than 6 months that began with a live birth (12.9%). They are also high for intervals of at least 75 months (7.2%) and for IPIs of less than 50 months that began with a miscarriage or stillbirth. Except for intervals of less than 6 months of duration, an IPI is most likely to end in a miscarriage if it began with one. All these relationships remain when the other covariates are controlled. For example, the relative odds of a miscarriage after an IPI of less than 6 months following a live birth are 3.30 (95% CI 2.77–3.90) when other covariates are controlled.

Stillbirth

For each IPI category less than 51 months in duration, rates of stillbirth are highest following preceding stillbirths; they are highest overall for IPIs of 27–50 months (9.0%) and nearly as high for those of 6–14 months (8.8%). For IPIs that began with other outcomes also, the rates of stillbirth do not vary much with IPI duration. Stillbirth rates are also elevated for IPIs of ≥75 months (3.6%) and for first pregnancies (3.3%) compared with the reference category of IPIs of 27–50 months that follow a live birth (2.5%).

Stillbirths are also more common after induced abortions for IPIs of 6–14 months (5.1%), 15–26 months (4.8%), and 27–50 months (5.3%). The lowest rate of stillbirth (1.3%) occurs among women who became pregnant within 6 months of a preceding induced abortion.

All these relationships remain when the other covariates are controlled, although the odds of stillbirth for first pregnancies are increased somewhat. The relative odds of a stillbirth after an IPI of less than 6 months following a live birth are 1.61 (95% CI 1.20–2.18) when other covariates are controlled.

Discussion

In our sample, more than 20% of IPIs of known duration are shorter than 15 months and nearly 10% are shorter than

6 months. Such short IPIs are much more likely than longer ones to begin with a NLB. For example, compared with IPIs of 27–50 months, IPIs of <6 months are 31 times more likely to begin with a miscarriage, 16 times more likely to begin with a stillbirth, and 6 times more likely to begin with an induced abortion. This most probably reflects the fact that women can become pregnant sooner (because of shorter postpartum anovulation) after a NLB and, for miscarriages and stillbirths, also that they are trying to replace the loss. As the durations of pregnancies are fairly similar for miscarriages and induced abortions, the fact that short intervals are much more common after miscarriages than after induced abortions does suggest replacement for the former.

IPIs shorter than 6 months after a live birth are associated with significantly increased odds of induced abortion, miscarriage (defined here as a spontaneous fetal loss prior to 28 weeks since the last menstrual period), and stillbirth. IPIs of 6–14 months after live births are also associated with an increased likelihood of induced abortion. These effects all become larger when other covariates are controlled.

Other studies have found effects of short intervals on stillbirths and fetal death. Studies using data from Sweden[10,17] found that very short (0–3 months) IPIs were associated with higher risks of stillbirth, although these relationships became somewhat weaker when maternal characteristics and preceding reproductive history were controlled. An investigation of World Fertility Survey (WFS) data from 40 developing countries[18] found IPIs of less than 9 months to be associated with higher risks of fetal death not controlling for other characteristics, but early fetal losses and stillbirths were combined in that study. In another study using the WFS data from eight countries,[19] multivariate models produced similar results when controlling for maternal age at conception, pregnancy order, maternal schooling, and place of residence. A study in Bangladesh, however, found no relationship between late fetal death (≥28 weeks of gestation) and short IPIs (<12 months) compared with intervals longer than 24 months.[9,20] A study in Ethiopia[21] found that abortions and stillbirths were much more common among birth-to-outcome intervals less than 1 year among a sample of 1549 pregnancies, but no other variables were controlled, and spontaneous abortions were grouped with induced abortions.

The increased odds of induced abortion associated with a short IPI after a live birth undoubtedly reflect the fact that women did not intend to become pregnant so soon after a previous pregnancy. However, this is not likely to be the case for stillbirths or miscarriages, most of which are unintended outcomes. For these, their higher incidence following short IPIs after a previous live birth probably reflects the fact that the woman had inadequate time to recuperate from the previous pregnancy, although some miscarriages may be caused by women intentionally engaging in activities (e.g. vigorous physical activity) that may increase their chance of pregnancy loss or it may be the case that some induced abortions are reported as being miscarriages. A finding of increased odds of adverse pregnancy outcomes after IPIs of less than 6 months is consistent with research that shows infant mortality to be higher for such intervals.[1]

We also find that pregnancy intervals of at least 75 months (which account for more than 6% of all IPIs of known duration in our study) are associated with increased odds of all three types of NLB outcomes that we investigate, although very long intervals are not as risky as very short ones that follow live births (and that follow induced abortions for the outcome of a subsequent abortion and that follow stillbirths for the outcomes of a subsequent stillbirth or miscarriage). Long intervals have also been found to be associated with higher risks of maternal morbidity[7] and maternal mortality[22] in Matlab and with a higher risk of stillbirths in Sweden.[10,17]

Our finding that induced abortions are more likely after short IPIs that began with a live birth and after very long IPIs is, to our knowledge, new. It strongly suggests that women care about the spacing of their births and want to have their pregnancies at least 15 months, but not more than 75 months, apart, corresponding to 2 to 7 years between births.

The lowest rates of induced abortion occur for IPIs of less than 26 months that follow miscarriages and stillbirths, probably because women who recently had a pregnancy that, unintentionally, did not result in a live birth want to replace the fetal loss. Rates of induced abortion are also low for first pregnancies. In Bangladesh, out-of-wedlock pregnancy is rare. It appears that most first pregnancies are indeed intended.

We have shown that the effects of IPIs differ considerably depending on the type of outcome that began the interval. Previous research on the effects of IPIs has generally not distinguished the type of pregnancy outcome that began the interval. An exception is the study of Conde-Agudelo *et al.*[13] that uses data on more than 250 000 pregnancies in Latin America that followed abortions. That study found that short post-abortion IPIs (<6 months) are associated with increased risks of maternal anaemia, premature rupture of membranes, low birthweight, very low birthweight, preterm delivery, and very preterm delivery, but they were not associated with increased risks of fetal death. The study of Conde-Agudelo *et al.* hypothesises that abortions, particularly induced abortions, may lead to reproductive tract infections, and these may lead to adverse pregnancy outcomes. However, the study was unable to distinguish between whether the preceding outcome was a spontaneous or induced abortion. Our results show that the risk of a subsequent induced abortion is relatively high when the preceding outcome is an induced abortion but relatively low when it was a miscarriage (or stillbirth). The fact that the study of Conde-Agudelo *et al.*[13] combines the first two and cannot distinguish between them may explain why that study did not find that short post-abortion IPIs were associated with higher rates of fetal loss.

We find that pregnancies after induced abortions are more likely to be terminated with a subsequent induced abortion, regardless of the duration of the IPI (up to 50 months). It appears that these women did not intend to become pregnant either time, regardless of the length of the interval between the pregnancies. Conde-Agudelo *et al.*[13] hypothesise that the higher risks of adverse pregnancy outcomes they find following abortions (spontaneous and induced combined) might be because of infections caused by the abortion, particularly induced abortions. However, we find that pregnancies following induced abortion are generally not associated with increased risks of miscarriage, but they are associated with increased risk of stillbirth. This lends some credibility to the notion that abortion may lead to an infection causing a stillbirth, although it is not clear why it would lead to a stillbirth but not a miscarriage.

Pregnancies after a miscarriage or stillbirth are more likely to result in a subsequent miscarriage or stillbirth, respectively, and this tends to occur irrespective of the interval between the pregnancies. This may be because of the physiological characteristics of the mother that are not measured in our data. A recent study in Sweden[23,24] found a positive correlation in the likelihood of miscarriages across pregnancies.

There are several reasons why short preceding IPIs may be associated with adverse pregnancy outcomes and why these effects might differ by the type of outcome that begins the interval. The maternal depletion hypothesis posits that women who become pregnant after a short interval are less able to provide nourishment during the second pregnancy because their bodies have had less time to recuperate from the previous pregnancy, and this might lead to reduced gestational duration, adverse pregnancy outcomes, and/or increased infant and child mortalities. For example, if women become pregnant again before folate restoration is complete, their subsequent offspring may be at a higher risk of folate insufficiency at the time of conception and throughout the pregnancy, leading to increased risks of neural tube defects, intrauterine growth restriction, and preterm birth.[25] Also, the uterus needs time to recover after a pregnancy. Full-term pregnancies are more depleting than those that are of shorter gestation, and hence, short intervals that begin with a live birth or stillbirth should have a more detrimental effect than those that began with a miscarriage or induced abortion. Also, if the pregnancy that begins the interval results in a live birth and the child is breastfed, lactation will further deplete the mother nutritionally.[26]

Sibling competition for parental time and resources is another explanation offered for the relationship between short intervals and higher rates of infant and child mortalities. With regard to pregnancy outcomes, 'competition' might occur if the previous pregnancy resulted in a live birth and the child from that preceding pregnancy introduces additional postpartum stressors on the mother.

Another possibility is that if the woman did not want to become pregnant soon after a previous birth, she may take less good care of herself and may engage in activities to try to end the pregnancy.

Disease transmission among closely spaced siblings is another explanation offered for the effect of short intervals or infant and child mortalities, but it should not apply to the case of pregnancy outcomes unless the infection of a previous liveborn (and still living) child is passed on to the fetus.

A different set of reasons may be at play in the case of long intervals between pregnancies. One possibility is that the physiology of a mother who becomes pregnant after a long interval is similar to that of a woman who is pregnant for the first time. This may explain why maternal mortality, preeclampsia, and eclampsia are more likely following IPIs longer than 59 months[7,22,27] and are similar to the levels for first pregnancies. In addition, some women may have health problems that both make it difficult for them to become pregnant (and hence they have long intervals) and increase the chance of fetal loss, raising some questions about whether the relationship between long IPIs and unintentional fetal loss is causal.

Even though the longitudinal survey design and excellent training of the field workers lead us to believe that the data we use here are of higher quality than those used in the vast majority of other studies, nonetheless, given the sensitive nature of reporting of adverse pregnancy outcomes, it is possible that there is some underreporting of induced abortions and fetal losses prior to 28 weeks. Some women may not recognise that they were pregnant or may fail to report to the CHW that they were pregnant. This is less likely to occur among women with stillbirth outcomes, as the duration of such pregnancies is considerably longer than for miscarriages and induced abortions. Compared with the results of a population-based study in India,[28] our estimates of induced abortions, miscarriages, and stillbirths are slightly higher than those found in India; that study found that 1.7% of all pregnancies resulted in induced abortions, 4.9% in miscarriages, and 2.1% in stillbirths. Compared with clinical studies, however, the rates of induced abortion, miscarriage, and stillbirths appear to be underreported in our data.[29] Nonetheless, underreporting of adverse outcomes would not bias our estimates of the effects of explanatory variables of interest if the underreporting is not correlated with those variables, and we have no reason to think otherwise.

Several other possible limitations should be noted. Information needed to calculate the duration of IPIs (the date of the previous outcome and the date of the last menstrual period before the index pregnancy) is missing for more than a sixth of the observations in our sample. If these cases differ systematically in unobserved ways from others, it could affect our results. In addition, the DSS defines miscarriages as spontaneous fetal losses that occur before 28 weeks since the last

menstrual period. This is a longer gestation than is used in most definitions of miscarriages, and hence, some of our findings about 'miscarriages' may not hold if they were defined using a shorter gestation. Furthermore, the sample area for the study in rural Bangladesh, the MCH–FP area of Matlab, has access to unusually good maternal and child health care and family planning services. This may result in fewer NLB outcomes as a result of better prenatal care and in fewer unintended pregnancies because of the good family planning services. Studies similar to this one should be conducted in communities in developing countries with a more typical level of resources. Also, the finding of higher rates of induced abortion after very short intervals that began with a live birth may not hold in developed countries where women may wish to have births close together to minimise their time out of the labour force. In addition, future research should investigate the effect of pregnancy spacing and type of preceding pregnancy outcome on gestational duration, birthweight, and maternal morbidity and mortality.

Conclusion

Women whose pregnancies are between 15 and 75 months after a preceding pregnancy outcome (regardless of its type) have a lower likelihood of miscarriages and stillbirths than those with shorter or longer IPIs. After a previous live birth, rates of induced abortion are lowest for IPIs of 15–50 months, which suggests that women in Matlab prefer to have their births 2 to 5 years apart. The lowest rates of induced abortion occur for IPIs of less than 27 months after a miscarriage of stillbirth, which is consistent with the notion that such women want to have a birth fairly quickly to 'replace' their recent unintentional fetal loss. Rates of induced abortion are also low for first pregnancies, suggesting that the vast majority of such pregnancies in our sample were intended and wanted.

If the preceding pregnancy ended in an induced abortion, the likelihood of a subsequent induced abortion is high regardless of the duration of the IPI. Women who have had an induced abortion should be counselled with regard to contraceptive options so that they can avoid another unintended pregnancy.

If the preceding pregnancy ended in a miscarriage or stillbirth, there is an elevated risk that the index pregnancy will end with the same outcome, regardless of the amount of time since the previous pregnancy ended. Women with a preceding fetal loss deserve special attention in counselling and monitoring.

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