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PAPER

The Effects of Birth Spacing on Infant and Child Mortality, Pregnancy Outcomes, and Maternal Morbidity and Mortality in Matlab, Bangladesh

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THE EFFECTS OF BIRTH SPACING ON INFANT AND CHILD MORTALITY, PREGNANCY OUTCOMES, AND MATERNAL MORBIDITY AND MORTALITY IN MATLAB, BANGLADESH[*]

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ABSTRACT

Using a large, high-quality longitudinal dataset on around 145,000 pregnancy outcomes gathered over a period of more than twenty years from an experimental setting in Matlab, Bangladesh, we seek a better understanding of the effects of the lengths of interbirth intervals on infant and child mortality and on maternal mortality and morbidity.

We find that, compared with intervals of 3-5 years in duration, preceding interbirth intervals of less than 24 months in duration are associated with significantly higher risks of early neonatal mortality, and that interbirth intervals of less than 36 months are associated with significantly higher risks of late neonatal mortality, post-neonatal mortality, and child mortality. Effects of short intervals are stronger the younger the child. A short preceding interval also increases the risk that the index pregnancy will result in a non-live birth (particularly an induced abortion) or a premature live birth. A short *subsequent* interpregnancy interval is also associated with a significantly higher risk of mortality for the index child. These effects persist when we control for potentially confounding factors (prematurity, breastfeeding, immunizations, and demographic and socioeconomic variables).

Women with short interpregnancy intervals have a significantly higher risk of pre-eclampsia, high blood pressure, and premature rupture of membranes compared to those with an interval of 27-50 months. A preceding interpregnancy of less than six months duration is associated with a somewhat elevated risk of maternal mortality compared to intervals of 27-50 months, but the relative risk is not statistically significant.

Women with very long interpregnancy intervals (75+ months) have a significantly higher risk of pre-eclampsia, proteinuria, high blood pressure, and edema compared to women with intervals of 27-50 months. Very long interpregnancy intervals are also associated with significantly higher risks of maternal mortality. However, long inter-outcome intervals do not significantly increase the risk of infant or child mortality.

A number of the relationships we find in our analyses of infant and child mortality and maternal morbidity are consistent with the maternal depletion hypothesis. We also find some support for the competition hypothesis

Pregnancies following short inter-outcome intervals (<36 months) are more likely to be to women who live in the Comparison Area of Matlab. This suggests that women in the MCH-FP Area are better able to use contraception to control the spacing of their pregnancies.

More than half (57 percent) of all inter-outcome intervals of known duration in our data are less than 36 months in length. Since intervals of less than 36 months are associated with higher levels of infant and child mortality and some maternal morbidities, there is plenty of opportunity in Bangladesh to reduce these adverse health outcomes by improving the spacing of pregnancies. Rates of infant and child mortality would be 5.8-9.4 percent lower if all inter-outcome intervals were 3-5 years in duration.

I. INTRODUCTION

There is renewed programmatic interest in the effects of birth spacing on infant, child, and maternal health and survival because family planning programs have the potential to affect the timing of pregnancies. For example, in response to recent research that suggests that birth intervals of at least three years may be associated with better health outcomes for mothers and children, communication campaigns in several countries have already begun using a 3-year spacing message. USAID is currently supporting the Optimal Birth Spacing Initiative, which seeks to provide advice on how programs can best promote optimal spacing. Understanding the size of the effects of birthspacing and reasons for them and identifying the groups for whom they are greatest will provide useful information for guiding the formulation of the most effective policies to improve birthspacing.

Every year nearly 11 million children die before their fifth birthday; 99 percent of these deaths occur in developing countries (UNICEF, 2003). The relationship between short birth intervals and high infant and child mortality has been established in a wide range of populations (e.g., Miller et al., 1992; Miller, 1991; Winikoff, 1983; Millman and Cooksey, 1987; Rutstein, 2000, 2003a, 2003b). In addition, several studies (e.g., Rutstein, 2000, in a cross-country analysis), show that very long intervals (at least five years in length) are associated a slight increase in mortality. However, few studies of the effects of birthspacing have adequately adjusted for potentially confounding factors such as prematurity, breastfeeding, whether the birth was intended, and socioeconomic factors. Adjusting for these characteristics, as we do in this paper, enables a clearer understanding of the size of the effects of birth intervals of various lengths, the reasons for these effects, and the population subgroups for which the effects are largest.

Every year over 54 million women suffer from complications during pregnancy and childbirth. Of those, about 1.5 million die; 99 percent of these deaths occur in the developing countries (World Health Organization, 1993; World Health Organization and United Nations Children's Fund, 1996). However, there have been only a few studies (e.g., Conde-Agudelo and Belizán, 2000) of the effects of pregnancy spacing on maternal morbidity and mortality. These suggest that very short intervals may be associated with

some types of morbidities, and that very long intervals may be associated with poorer outcomes also. In this paper we assess the extent to which pregnancy spacing affects maternal morbidity and mortality in Bangladesh, and whether programs that attempt to change birthspacing patterns can help reduce such adverse outcomes for women. Such a health rationale has long been one of the reasons for supporting family planning programs in developing countries.

Using a large, high-quality longitudinal dataset gathered over a period of more than twenty years from an experimental setting in Matlab, Bangladesh, we seek a better understanding of the effects of the lengths of birth intervals on infant and child mortality and on maternal mortality and morbidity. We also consider how the length of time since the last birth or pregnancy affects whether a pregnancy results in a live birth (vs. a miscarriage, abortion, or stillbirth) and the duration of pregnancy. This paper addresses the following research questions:

1) To what extent does the length of the preceding birth interval affect the risks of infant and child mortality?

2) Are the interval effects U-shaped, i.e., are both too short and too long intervals pernicious? (and exactly what durations define too-short and too-long?)

3) To what extent is the "effect" of longer interbirth intervals due to there being a non-live birth between the two births that define the interval? How do the effects of inter*birth* intervals compare to those of inter-*outcome* intervals (the interval back to the last pregnancy outcome, regardless of whether it was a live birth)?

4) To what extent is the effect of a short inter-outcome interval on infant and child mortality due to short gestation of the index pregnancy? What are the separate effects of the interpregnancy interval (the interval between the preceding pregnancy outcome and the conception of the index pregnancy) and of the duration of gestation of the index pregnancy?

5) To what extent are the apparent effects of short or long intervals on infant and child mortality due to factors such as breastfeeding and immunizations that are correlated with pregnancy spacing?

6) At what ages of child are the interval effects greatest? In particular, do the effects of the length of the preceding interval differ across subperiods of infants and childhood?

7) Does the duration of the *subsequent* interval affect the likelihood of survival of the index child when appropriate attention is given to the reverse causality that can arise because subsequent intervals may be short *because* the index child died?

8) To what extent do the effects of short intervals on infant and child mortality appear to be due to maternal depletion? To what extent do they appear to be due to competition among closely spaced siblings?

9) Does the interval between the preceding pregnancy outcome and the conception of the index pregnancy affect the outcome of the index pregnancy (whether it results in a live birth or not) and duration of the gestation of the index pregnancy, e.g., whether the baby is born prematurely?

10) How does the length of the interpregnancy interval preceding a pregnancy affect the *woman's* likelihood of morbidity during that pregnancy and her chance of dying from pregnancy-related causes? Are the interval effects on maternal outcomes U-shaped, i.e., are both too short and too long intervals pernicious?

11) Do the effects of intervals on infant, child, and maternal health and survival remain when those of other potentially confounding variables (e.g., mother's age and education) are controlled?

12) How do the magnitudes of the health risks associated with "high-risk" inter-outcome intervals compare to those for other explanatory variables associated with a higher risk of poor maternal, infant, and outcomes?

13) Do the effects of intervals differ across subgroups of the population? Are there certain subgroups for whom effects are larger than others?

14) What are the characteristics of the women who have the intervals lengths associated with poorer pregnancy, infant, child, and maternal outcomes?

In Chapter II we briefly review the reasons why pregnancy spacing might affect pregnancy outcomes, infant and child mortality, and maternal morbidity and mortality, and what the literature has found about these relationships. Chapter III describes the setting for our study and the data and methods we use in our analyses. The next three chapters present the results of our analyses of infant and child mortality and pregnancy outcomes (Ch. IV), maternal mortality (Ch, V), and maternal morbidity (Ch. VI) and discuss their implications. Chapter VII describes the characteristics of women who have very short and very long intervals. The final chapter presents our conclusions.

II. WHY BIRTH SPACING MIGHT AFFECT PREGNANCY OUTCOMES, INFANT AND CHILD MORTALITY, AND MATERNAL MORBIDITY AND MORTALITY

There is limited empirical evidence on the intervening process through which preceding/subsequent birth intervals operate to influence perinatal, infant, and child mortality. The adverse consequences of a short interval for infant and child survival and maternal mortality and morbidity have been attributed to the biological effects related to the "maternal depletion syndrome" or more generally the woman not fully recuperating from one pregnancy before supporting the next one (which, may lead, for example, to anemia and premature rupture of membranes). (For recent literature reviews, see Conde-Agudelo, 2004, and Dewey and Cohen, 2004.) Other mechanisms that have been hypothesized to possibly contribute to a detrimental effect of a short preceding interval on infant and child survival are (1) behavioral effects associated with competition between siblings (e.g., competition for parental time or material resources among closely-spaced siblings), (2) the inability (or lack of desire) to give a child adequate attention if his or her birth came sooner than desired; and (3) disease transmission among closely spaced siblings. Several of these have been discussed extensively in the literature (e.g., DaVanzo et al., 1983; National Research Council, 1989; Miller, 1991). Much less attention has been given to why very *long* intervals might have an adverse effect; Conde-Agudelo and Belizán (2000) provide a nice discussion about this. Note that some of these mechanisms, e.g., maternal depletion, apply to preceding pregnancies regardless of the outcome, though they may depend on the duration of the preceding pregnancy, while others, e.g., competition and spread of disease, will only come into play if the preceding child is still alive.

There are a number of reasons why there may *appear to be* a relationship between pregnancy- and birth-spacing on the one hand and pregnancy, infant, child, and maternal outcomes on the other hand without the effect being causal. For example, holding constant the length of time between a preceding birth and the conception of the index pregnancy, the shorter the duration of index pregnancy, the shorter will be the interval between births. Since prematurity increases the risk of infant mortality, a shorter gestation of pregnancy could be a reason why a short preceding interbirth interval is

related to infant mortality. Or interbirth intervals may be long because there is an intervening non-live birth, and the types of women who have non-live births may also be less healthy or give birth to less healthy children. As another example, if women who are less careful about their own and their children's health care tend to the ones who have shorter intervals, an apparent effect of short intervals when no other variables are adjusted for may actually reflect these other factors. Other possibilities are that longer breastfeeding both improves infants' survival chances and lengthens the intervals following their birth. This could explain a relationship between the length of the *subsequent* pregnancy interval and the survival of the child born at the beginning of that interval.

Further review of relevant literature can be found in Chapters IV, V, and VI ahead.

III. STUDY SETTING, DATA, AND METHODS

Study Setting and Data

Our study uses data from the Matlab subdistrict of Bangladesh, a poor, traditional, religiously conservative, country in South Asia. The rural Bangladeshi subdistrict of Matlab is well known for its Demographic Surveillance System (DSS), operated by the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B). Since 1966, the Centre for Health and Population Research of the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B) has maintained a Demographic Surveillance System (DSS) that covers a large population (220,000 people in 2002) and has collected data on pregnancy outcomes in two otherwise-similar areas—the "Treatment" and "Comparison" Areas. The Comparison Area is typical of much of Bangladesh in contraceptive practice (ICDDR,B Centre for Health and Population Research, 2000), fertility (Mitra et al., 1994), abortion (Khan et al., 1986), and maternal mortality (Alauddin,1986; and Khan, Jahan, and Begum, 1986). The DSS collects information on pregnancies, births, deaths, migrations, marriages, divorces, and household splits. Currently DSS events are collected by Community Health Research Workers (CHRWs)[1] through monthly household visits, supervised by a Field Research Supervisor (FRS). (Until 1999, CHRWs recorded events through fortnightly household visits and, accompanied by the Field Research Supervisor (FRS), visited the household every six weeks to complete the DSS registration form.)

The DSS data we use to study pregnancy outcomes, and infant, child, and maternal mortality contain information on a large number of pregnancies and births (145,816 pregnancies and 128,328 births between 1982 and 2002), a sizable number of infant and child deaths (around 13,556 deaths before age 5), and a considerable number of maternal deaths (450 between 1982 and 2002). The DSS data on the timing of pregnancy outcomes and of deaths are of very high quality because they have been collected during regular household visits (every two weeks until 1997 and every month since then) by trusted female community health workers.

[1] These workers used to be referred to as Community Health Workers (CHWs) and are referred to as such in much of the rest of this report.

Since October 1977, half of the DSS area has been exposed to the MCH-FP intervention of the ICDDR,B, which provides better family planning and health services, while people in the other half of the area, known as the Comparison Area, receive the standard government services.[2] In addition to the standard government Health and Family Welfare Centres available in both areas, the Treatment Area also has ICDDR,B sub-centres that provide maternal and child health and family planning services that are better than those available in the Comparison Area.[3] Contraceptive use, antenatal care, child immunization, and utilization of other child health services are all substantially greater in the MCH-FP (or "Treatment") Area than in the Comparison Area. This has resulted in lower fertility and mortality in the MCH-FP Area compared to the Comparison Area. The fertility and mortality differences between the areas have become smaller over time due to improvements in the government services, but they are still substantial. The experimental difference in the services between the two areas allows us to compare the effects of more intensive family planning and health services with those of more limited services while holding other key factors constant and to see if the effects of birthspacing differ between the two areas.

There are four health centers in the MCH-FP Area; each covers a population of over 25,000. These centers are equipped to provide basic emergency obstetric care for the catchment area and are posted with a trained nurse-midwife along with a paramedic. These nurse-midwives and paramedics have been trained to provide antenatal care, treat minor pregnancy and delivery complications, conduct normal deliveries, and refer cases with serious complications to Matlab Hospital. At the health center, the nurse-midwife examines the women clinically and administers simple laboratory tests. A substantial portion of the health information is also verified by a female medical officer who visits the center from the Matlab head office every week.

[2] Married women in the Comparison Area were supposed to (but didn't always) receive the standard visits every two months from female welfare assistants of the government family planning program who provide counseling and supply pills and condoms. In the Treatment, or MCH-FP, Area, community health workers (CHWs) visited married women of reproductive age every two weeks to provide counseling about family planning services and to deliver injectables, pills, and condoms at the doorstep.

[3] E.g., the MCH-FP Area is characterized by greater contact among clients, workers, and supervisors as well as greater availability and a broader mix of contraceptive methods than is available in the Comparison Area.

The data for our analyses of maternal morbidity come from the MCH-FP Area of Matlab, which has a population of over 100,000. Since 1996, the Reproductive Health Unit of the ICDDR,B has been collecting data on maternal morbidity from women who visit a health center for an antenatal check-up. In the MCH-FP Area, all pregnant women are given a card, known as the "pictoral" card, by the community health research worker (CHRW) when their pregnancies are identified by the CHRWs during their monthly household visits for collecting data for the DSS and also for the Record Keeping System (RKS). The woman keeps the card and brings it when visiting the health center for service. The card was designed to record not only service uptake information, including antenatal check-up, delivery and postnatal check-up, but also contains behavior change communication messages regarding, for example, pregnancy danger signs, pregnancy planning and maternal nutrition. More information about these data is provided in Chapter VI.

Another strength of the Matlab data for our analyses of pregnancy outcomes and infant, child, and maternal mortality is that they cover a long period of time (early 1980s to early 2000s) during which there have been remarkable changes in fertility and mortality in Bangladesh. The total fertility rate declined from 6.5 children per woman in the mid-1970s to 3.2 in 1998-2000, and the infant mortality rate declined from 100 infant deaths per 1,000 live births in the mid-1970s to 67 per 1,000 in 1998-2002. During the same period, the child mortality rate (1-4 years) declined from 25 per 1,000 to 6 per 1,000, and the maternal mortality ratio declined from about 5 to 3.2 per 1,000 live births (NIPORT, Macro, JHU, and ICDDR,B, 2003). However, even though mortality rates have fallen, their levels are still relatively high and provide large numbers of deaths for analysis. For example, the infant mortality rate in Bangladesh in the year 2000, of 60 infant deaths per 1,000 live births, was 12 times the average in "high-income" countries, and the under-five mortality rate, of 83 deaths before the fifth birthday per 1,000 live births, was nearly 14 times the average in "high-income" countries (World Bank, 2002).

Moreover, our data contain information on a number of variables that may affect birthspacing and/or mortality or morbidity, e.g., age and education of the mother, household space (a proxy for the household's economic status), religion, duration of the pregnancy, contraceptive use, breastfeeding, whether the pregnancy was intended, and

the immunization status of children under the age of five. These may affect pregnancy spacing, and they may also the outcomes that we consider, and, if not controlled, could contribute to associations between birthspacing and these outcome measures. Some of these data have been collected for the entire Matlab area, while others, at least until recently, were only collected in the MCH-FP Area.

Methods

Dependent Variables and the Samples Used for Analyses of Them

Our analyses of infant and child mortality consider the following dependent variables and samples:

- **early neonatal mortality**: whether a live-born child died in the first week of life. This analysis uses a sample of the 125,720 live singleton births reported in the DSS. Of these, 3,631 (2.9%) died during the first week of life.
- **late neonatal mortality**: whether an infant who survived the first week of life (n = 121,936) died in the next three weeks. Of these, 1,734 (1.4%) died during the second through fourth week of life.
- **post-neonatal mortality**: whether an infant who survived the first four weeks of life (n = 119,718) died before his or her first birthday. Of these, 3,684 (3.1%) died during this subperiod.
- **child mortality**: whether children who survived until their first birthday (n =110,191) died before their fifth birthday. Of these, 3,323 (3.0%) died between their first and fifth birthdays.

Because multiple births have a considerably higher risk of mortality, we exclude them (3,043 children in all) from most of our analyses of infant and child mortality.

We also conduct an analysis where **pregnancy outcome** is the dependent variable. In this analysis, the sample is 142,773 reported pregnancies that occurred between 1982 and 2002, resulted in a singleton live birth or a non-live birth, and are documented in the DSS data. We explain when whether the pregnancy ended with a miscarriage (5.6%), induced abortion (3.3%), stillbirth (3.0%), or live birth (88.0%). For this same sample we also estimate equations explaining the duration of pregnancy, separately for pregnancies that ended with a live birth or stillbirth, a miscarriage, or an induced abortion.

For our analyses of **maternal mortality**, the sample is 142,948 pregnancies that occurred between 1982 and 2002, of which 363 died during pregnancy or in the 42 days following pregnancy from pregnancy- or birth-related causes. The number of maternal deaths in our data is considerably greater than the number that Conde-Agudelo and Belizán (2000) consider in their widely cited study of the effects of interpregnancy intervals on maternal mortality in Latin America, despite the fact that we have data on only about one quarter the number of pregnancies that they considered.

Our analyses of **maternal morbidity** use data from the "pictoral" cards described above and focus on complications that occurred during the third trimester of pregnancy (170 days or more after the last menstrual period). These analyses are based on information on women who visited health centers during their third trimester of the pregnancy. If the woman made more than one visit during the third trimester, we consider the last such visit. Data on maternal morbidity from the "pictoral" cards are supplemented with data from the DSS database on maternal age, pregnancy history (gravidity and loss of pregnancy), education of women, household space, and religion.

The DSS identifies 21,244 pregnancy outcomes in the MCH-FP Area that occurred in the study period during which data on maternal morbidity were collected (1996-2002). We focus on 11,122 (52.4%) of these in which the woman came to the health center for antenatal check-up during the third trimester of the pregnancy.[4] We consider the last visit the woman made during the third trimester.

The pregnancy complications we consider are:

- **high blood-pressure** (diastolic 90 mm Hg or greater), which is found for 3.3 percent of our observations;
- **anemia** (clinical), which is found for 18.6 percent of our observations;
- **edema** (clinical), which is found for 21.9 percent of our observations;
- **proteinuria** (clinical), which is found for 4.4 percent of our observations;
- **bleeding** (clinical), which is found for 0.5 percent of our observations;

[4] Our analyses exclude 8,879 pregnancies of women who had no antenatal visits and 1,243 where the woman visited the health center during the first or second trimester but not during the third. In Chapter VI, we explore the differences between the women who visited a health center during their third trimester of pregnancy and those who did not.

- **premature rupture of membranes** (clinical), which is found for 1.5 percent of our observations; and
- **pre-eclampsia**, which is defined as the presence of any two of the three conditions of edema, proteinuria, or high blood pressure; this is found for 2.7 percent of our observations.

Measures of Interbirth and Interpregnancy Intervals

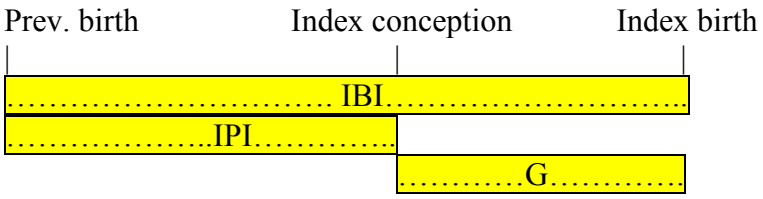
Many previous studies of the effects reproductive spacing on infant, child, and maternal health and survival have used data from birth histories and have considered the interval between births – the interbirth interval – as their measure of spacing. This is probably the appropriate measure for looking at the effect of competition from another young child in the family. (In fact, for this to be the case, that preceding child had to have survived to the time under consideration.)

However, the interbirth interval includes the duration of the index pregnancy, which may have its own effect of infant and child mortality. Furthermore, in some cases there is a non-live birth between two live births, in which case the interbirth interval will include two (or more) interpregnancy intervals. Some of the hypotheses about why reproductive spacing may affect maternal and infant health and survival have to do with the interpregnancy interval. E.g., it is the interval between pregnancies (and, for live births, perhaps after the end of intensive breastfeeding) during which the woman "recuperates" from the preceding pregnancy. Furthermore, an intervening non-live birth may reflect something about the mother's health that may affect her risk of mortality during a subsequent pregnancy or the health of her children. The diagrams below illustrate these concepts.

1. Interbirth interval duration (IBI) = Birth date of index child - birth date of preceding live birth
2. Inter-outcome interval duration (IOI) = Date of termination of index pregnancy - Date of termination of preceding pregnancy (even if preceding pregnancy had a non-live birth outcome)

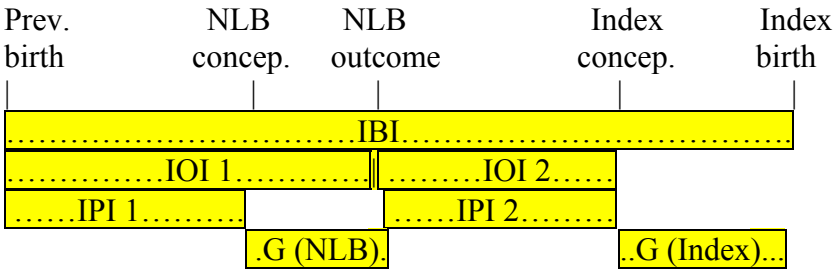
3. Interpregnancy interval duration (IPI) = Date of termination of index pregnancy - Date of conception of preceding pregnancy = Inter-outcome interval - Duration of gestation of index pregnancy.

If there is no intervening non-live birth, the interbirth interval (IBI) will be the duration of the preceding interpregnancy interval (IPI) plus the gestation of the index pregnancy (G).



In this case IBI = IPI + G, or IPI = IBI – G.

If there is an intervening non-live birth (NLB), the interbirth interval will include two (or more) inter-outcome intervals, each of which consists of an interpregnancy interval and the duration of the pregnancy that follows it.



Ideally we would like to include measures of both the duration of gestation of the index pregnancy and the duration of the interpregnancy interval that precedes it in our model. Gestation has its own independent effects on infant mortality (babies born prematurely are more likely to die). This is better than using the combined inter-outcome intervals (which is the sum of interpregnancy interval and gestation), because we want to parse out the effects of both short gestation and the effects of short intervals.

Unfortunately, we do not have gestation data for our full sample, and there are systematic differences between the sample with data on the duration of pregnancy gestation and the sample without this information. Excluding pregnancies that resulted in twins and triplets, we have data of the duration of the pregnancy for 71,554 pregnancies,

but this information is missing for 71,218 pregnancies. Not only are gestation data not available for the Comparison Area until recently, but also, within the MCH-FP Area, the children of the women for whom we don't know gestation are more likely to die during infancy or childhood than those for whom we do know gestation. Rather than focus only on this selected sample and lose many cases in the process, we use the approach of considering the entire sample, including gestation for those for whom we know it and including a missing dummy variable identifying those for whom we don't know the duration of gestation. We are able to show mathematically that if we include inter-outcome intervals *and* gestation in the models, the estimated effect of inter-outcome intervals would be the same as the effect of interpregnancy intervals. In particular, if the effects of intervals and gestation are linear, the coefficient (b) for the inter-outcome interval variable will be the same as if it were the interpregnancy interval.

$$IOI = IPI + G \qquad (1)$$

$$IPI = IOI - G \qquad (2)$$

$$IM = a + b\,(IPI) + c\,(G) \qquad (3)$$

$$IM = a + b\,(IOI - G) + c\,(G) \qquad (4) \quad \text{(using Equation 2 for IPI)}$$

$$IM = a + b\,(IOI) - b\,(G) + c\,(G) \qquad (5)$$

$$IM = a + b\,(IOI) + (c-b)\,(G) \qquad (6)$$

Where

IOI = The duration of the inter-outcome interval

IPI = The duration of the interpregnancy interval

G = The duration of gestation of the index pregnancy

IM = Infant mortality of the index birth

I.e., even though IPI refers to time between pregnancies and IOI refers to time between outcomes, their coefficients (b) are identical.

Hence, for a linear specification, it is sufficient to use IOI (which we know for the vast majority of our sample) instead of IPI (which we can calculate accurately only for a

selected sample) as long as we also control for G. Although in our empirical analyses of infant and child mortality in Chapter IV we allow the effect of both IOI and gestation to be nonlinear (by using dummy indicators for categories of durations), the effects we estimate for our indicators of IOI should give us essentially the same ones we would get if we'd used indicators of IPI as long as we also control for G. Granted, we don't know G for many cases, but we deal with this by including an additional control for Gestation Unknown.

The analyses of maternal mortality assign a duration of pregnancy depending on the outcome of the pregnancy and use this to estimate the duration of the interpregnancy interval. In the analyses of maternal mortality and morbidity, the interpregnancy interval is defined as the time elapsed between the woman's last pregnancy outcome and the date of the last menstrual period for the index pregnancy. Although conception typically occurs at two weeks (or more) after the last menstrual period, the measure we use is the same as that used in the recent study by Conde-Agudelo and Belizán (2000), to which we compare our results. For calculating the interpregnancy interval, the date of the preceding pregnancy outcome was taken from the DSS database using unique identification number maintained by the system. These methodologies are described in more detail in Chapters V and VI, respectively.

In our analyses of infant and child mortality, we investigate the effects of seven categories of inter-outcome intervals:

- less than 15 months between the preceding outcome and the birth of the index child
- 15 months to 17 months
- 18 months to 23 months
- 24 months to 35 months
- 36 months to 59 months
- 60 months to 83 months, and
- 84 or more months.

We have chosen these categories to correspond to those used in previous studies and those considered in the policy debate (e.g., whether to change the recommendation that births should be spaced at least two years apart to a recommendation that the optimal interbirth interval is three to five years), but also consider subgroups between which we found significant differences (e.g., 60-83 months vs. 84 or more months). We have looked at subgroups within the interval categories mentioned above (e.g., each one-year group within the 3-5-year category), but the effects of these various subgroups didn't differ significantly from one another, so we have combined them.

Because of our large number of observations, we have large sample sizes for each of the intervals we consider; these are shown below in Figures III-1 and III-2. This allows us to look at narrower distinctions and shorter birth intervals than many previous researchers have. For example, Cleland and Sathar (1984), Rutstein (2003), and Koenig et al. (1990) used interval groupings that were defined as <2 years, 2-3 years, 3-4 years, and 4+ years. Miller et al. (1992) considered shorter intervals, but only investigated a dichotomous distinction of <15 months versus 15 or more months. Thus our analysis provides a more detailed look at the risk associated with each interval length.

Our analyses that consider interpregnancy intervals (e.g., our analyses of maternal outcomes) consider groupings that correspond to the above categories for full-term index pregnancies. E.g., the shortest interval in those analyses is an interpregnancy interval less than 6 months, which corresponds to inter-outcome interval of less than 15 months that ended in a full-term live birth.

Our sample also includes first pregnancies, for which there isn't a length of the preceding interval. The analyses include a dichotomous indicator for first parity to identify such births and adjust for the fact that first births tend to have poorer outcomes. Our sample also includes some pregnancies for which we don't know the length of the preceding interval (e.g., because the preceding outcome occurred before our study period or before the woman migrated into the study area). This group is identified by a "missing information" dichotomous indicator.

Distributions of Inter-Outcome and Interbirth Intervals

Excluding pregnancies that resulted in live-born twins and triplets, there are 142,773 pregnancy outcomes in our sample. Approximately 29 percent of those are from first pregnancies, and hence don't have a preceding interpregnancy interval. In addition, for 22,770 non-first pregnancies, we do not know the date of the preceding pregnancy outcome, and hence do not know the length of the preceding inter-outcome interval. This generally occurs because the preceding pregnancy occurred either before the study began or because the woman migrated into the study area between the preceding and the index pregnancy. All remaining pregnancies are associated with an interbirth and an inter-outcome interval. The total number of interbirth intervals is smaller than the number of inter-outcome intervals because there are fewer live births than pregnancies.

The distributions of the inter-outcome and interbirth intervals of known duration are depicted in Figures III-1 and II-2, respectively. Of inter-outcome intervals of known duration, 9,622 are less than 15 months in duration. As a percentage of all inter-outcome intervals of known length this is 11.1 percent. Because interbirth intervals sometimes contain more than one inter-outcome interval, the number (n = 3,049) and percentage (4.3%) of interbirth intervals of known duration that are less than 15 months in duration are considerably smaller. In all, 57 percent of all inter-outcome intervals of known duration and 49 percent of all interbirth intervals of known duration are less than 36 months in length. Intervals of 84 months duration or longer account for 4.4 percent of inter-outcome intervals of known duration and for 5.1 percent of interbirth intervals of known duration.

Figure III-3 provides shows a distribution of the interpregnancy intervals among women in the MCH-FP Area. As described above, we must know the gestation duration in order to calculate the interpregnancy interval, so we only show the distribution for the cases for which we have this information. Among the pregnancies for which we know the duration of gestation, slightly over 42 percent of them were preceded by an inter-pregnancy interval of less than 27 months, which is comparable to a three-year interval between births for index pregnancies that last nine months. As we will see ahead, short intervals are less common in the MCH-FP Area than in the Comparison Area.

Figure III-1. Distribution of Inter-Outcome Intervals of Known Duration, in Months (excluding first pregnancies and index pregnancies that resulted in twins or triplets) (n=86,752)

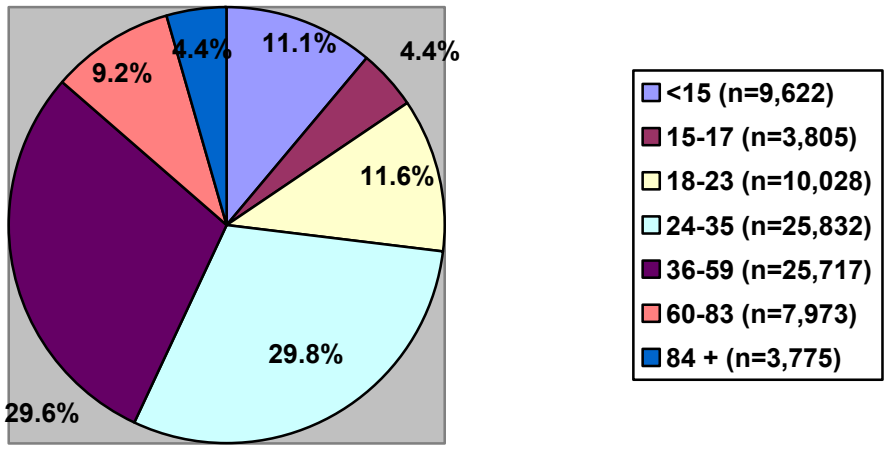


Figure III-2. Distribution of Interbirth Intervals of Known Duration, in Months (excluding first births and index births that resulted in twins or triplets) (n=71,641)

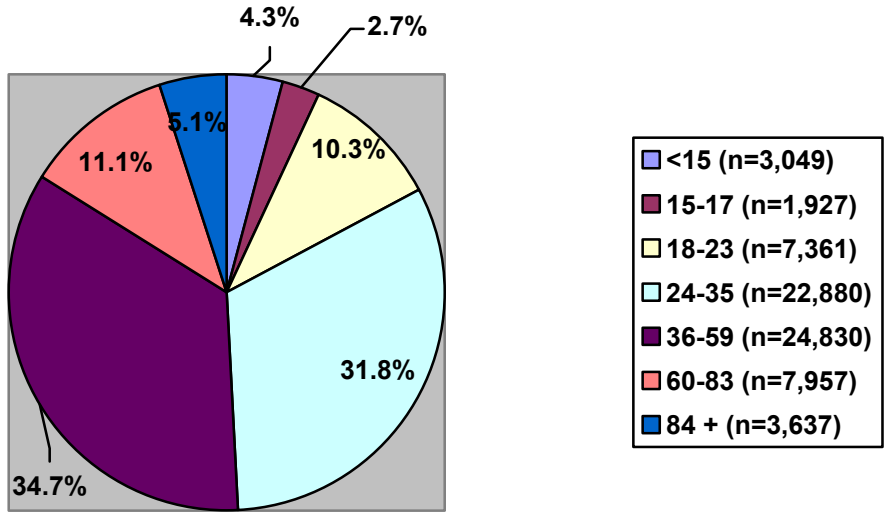
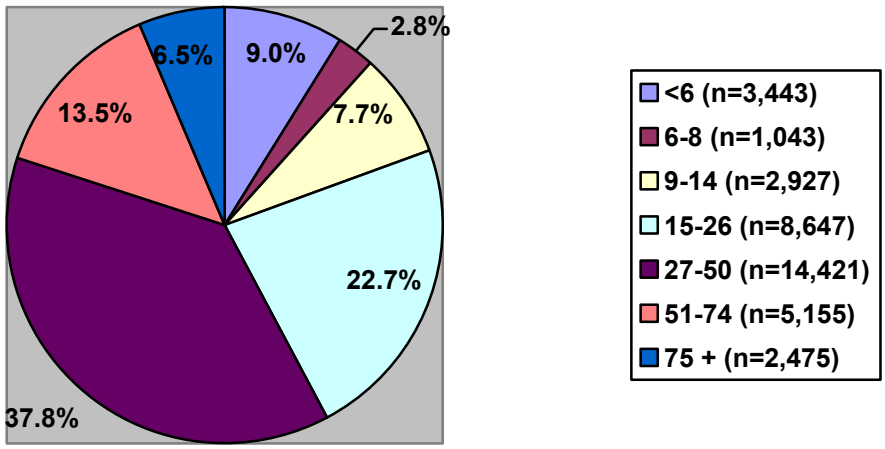


Figure III-3. Distribution of Interpregnancy Intervals of Known Duration, in Months, in the MCH-FP Area (excluding first pregnancies and index pregnancies that resulted in twins or triplets) (n=38,121)



Methods of Estimation

For each of our dependent variables, we estimate an equation explaining the influences on it of the length of the preceding interval, parity, and other explanatory variables (which are described below and their means can be seen in Appendix Table 1). We conduct sensitivity analyses to assess whether the results change depending on the measure of intervals that we use and on which other explanatory variables are controlled.

For each of the dependent variables for infant and child mortality, we estimate a Cox proportional hazards model explaining whether the child died during the subperiod under consideration. This technique enables us to include censored observations in our analyses (e.g., children who were less than 5 years old at the end of our study period or those who migrated out of the study area before the end of the subperiod under consideration).

When pregnancy outcome is our dependent variable of interest, we estimate a polytomous logit regression that explains how the explanatory variables affect the

likelihood of a miscarriage, abortion, or stillbirth, relative to the likelihood of a live birth. We use OLS to estimate equations explaining the duration of pregnancy.

For maternal morbidity and mortality, we estimate logistic regressions, one for each symptom/complication considered for the analyses of morbidity.

We have data on 145,816 pregnancies to 56,511 women. We have used the Cluster command in Stata 7.0 to adjust for the possibility of correlation among pregnancies to the same woman. Adjusting for clustering does not affect the estimates of coefficients, but it does alter the standard errors. In all models for which we ran models that were both adjusted and not adjusted clustering, we did not find much variation in the levels of significance due to clustering. Correcting for clustering never changed a coefficient's level of significance to a lesser level, e g., from $p<.01$ to $p<.05$. The standard errors that we report ahead are not corrected for clustering.

We examine how the effects on each dependent variable differ across our various interval categories and how these patterns vary across our various dependent variables. We also assess whether the interval effects change when other covariates, which may be correlated with both the dependent variable and external duration, are controlled. This enables us to see the extent to which the interval effects we see when no other variables are controlled appear to be due to differences in the types of women who have intervals of different lengths. For example, if more highly educated women are better able to space their births and take better care of their children, an apparent effect of short intervals when no other variables are controlled may in part reflect differences in education. We also use interactions to explore whether the effects of inter-outcome intervals on a given dependent variable differ across subgroups. E.g., are the effects of short intervals stronger or weaker in the more recent years covered by our data? Are they stronger or weaker for the women who live in the MCH-FP Area, which has better family planning services than the standard government services available in the Matlab Comparison Area?

We also look at the characteristics of women in each interval category to see if there are significant differences among those who have short- and medium-length intervals and those who have very long intervals (which have been found to be detrimental in several recent studies).

IV. EFFECTS OF BIRTH AND PREGNANCY SPACING ON INFANT AND CHILD MORTALITY AND PREGNANCY OUTCOMES

In this chapter, we describe our analyses of the effects of intervals on infant and child mortality. First we detail the differences between the effects of interbirth and inter-outcome intervals on mortality in different subperiods of infancy and childhood. Next we show how the effect of a short interval on first-week mortality varies depending on the outcome of the preceding pregnancy. Then we compare the results of our analyses before and after controlling for potentially confounding variables. After that, we investigate interactions between intervals and other characteristics (to see if interval effects vary across subgroups), and we compare the magnitudes of the effects of short intervals to those of other high-risk factors. In the next subsection, we explore whether including breastfeeding and immunization data in the models reduces the effects of short intervals on mortality; this analysis uses only the MCH-FP sample. Within the MCH-FP sample, we also estimate models explaining pregnancy outcomes and gestation length. Returning to the full sample, we run a simulation of how infant and child mortality would change if all inter-outcome intervals were between 3 and 5 years in length. Finally, we present an analysis that investigates the role of reproductive behaviors in explaining the mortality differences between the MCH-FP Area and the Comparison Area. We conclude this by discussing with the conclusions and implications of these various analyses.

Effects of Interbirth and Inter-Outcome Intervals and of Controlling for Gestation of Pregnancy on Infant and Child Mortality

In this subsection, we show the results of Cox proportional hazards models for four subperiods of infancy and childhood: the early neonatal period (first week of life), the late neonatal period (the second through fourth week of life), the post-neonatal period (week five through week fifty-two), and childhood (age one year to five years). We estimate three models for each of these subperiods some of the results are graphed in Figures IV-1a-d. The full results are shown in Appendix Table 2a-d, and. In Figures IV-1a-d, the model indicated by squares shows the relative risks of *interbirth intervals* (live birth to live birth) of different lengths on mortality relative to interbirth intervals of three and five years in duration. The model indicated by triangles shows the relative risks of

inter-outcome intervals of various lengths on mortality relative to an interval of three to five-years. Both of these models control for no other characteristics, except for first birth. One reason that both interbirth intervals and inter-outcome intervals may be short is because the gestation of pregnancy may be short. Since gestation of pregnancy is indeed strongly related to survival, we then add in control variables for the duration of pregnancy in two-week intervals. This model is shown in diamonds in Figures IV-la-d.

As shown in Figures IV-1a-d, for all of these subperiods, the size of the effect of short intervals decreases when the definition of interval changes from interbirth interval to inter-outcome interval. For example, for pregnancies occurring after an interbirth interval of less than 15 months, the relative risk of first-week mortality is 3.90 ($p<.001$) compared to an interbirth interval of three to five years. When inter-outcome intervals are considered instead, the relative risk of first-week mortality associated with an interval less than 15 months is 2.05 ($p<.001$) compared to an interval of three-to-five-years. This finding of short interbirth intervals having a higher risk than similarly short inter-outcome intervals extends through all four subperiods of infancy and childhood. The difference between the effect of interbirth intervals and inter-outcome intervals is largest for neonatal mortality and is still substantial for the post-neonatal period, but it is much smaller for child mortality. Adding a control for duration of pregnancy to the model that includes inter-outcome intervals reduces the size of the effect of short intervals but to a relatively small extent. For example, for babies born after an inter-outcome interval less than 15 months, the relative risk of first-week mortality is reduced from 2.05 ($p<.001$) to 1.85 ($p<.001$) with the addition of the variables measuring the duration of pregnancy. Short gestation of pregnancy (prematurity) increases the risk that a baby will die in the early neonatal, late neonatal, and post-neonatal periods, though it does not have a significant effect on childhood mortality. Very long gestation (40 weeks or more) is also associated with an increased risk of mortality (relative to a gestation of 36-37 weeks) during the early neonatal period.

It is noteworthy that the highest-risk interval changes as the subperiod of life studied progresses. During the neonatal periods, the highest risk of mortality is associated with the shortest (<15-month) inter-outcome intervals (RR=1.85, $p<.001$ for early neonatal and RR=1.50, $p<.001$, for late neonatal mortality, in the model with

controls for gestation). During the post-neonatal period, the highest relative risk of mortality is associated with inter-outcome intervals of 15-17 months (RR=1.6, p<.001 in the inter-outcome interval model with controls for gestation). Finally, during childhood, the highest relative risk of mortality is associated with inter-outcome intervals of 18-23 months (RR=1.44, p<.001, in the inter-outcome interval model with controls for gestation).

Another noteworthy result is that we do find a significant detrimental effect of very long inter*birth* intervals (84+ months) on first-week mortality, but we don't see a significant effect of long inter-*outcome* intervals of this length.

How Do Effects of Short Inter-Outcome Intervals Vary by the Type of Outcome of Preceding Pregnancy?

The difference between the interbirth interval and inter-outcome interval is that inter-outcome intervals start counting from the preceding pregnancy outcome, regardless of its type, whereas interbirth intervals start the clock from the preceding live birth. As we show later (in Chapter VII), many of the very short inter-outcome intervals occur among women who recently had a non-live birth outcome (i.e., the outcome that begins the inter-outcome interval is a non-live birth). Since a preceding non-live-birth outcome may be less depleting than a preceding live birth, both because the preceding pregnancy may be shorter and because there was no breastfeeding, we explored for interactions between short intervals and preceding non-live births. We find significant interactions between the shortest inter-outcome interval and the type of the preceding pregnancy outcome. As shown in Figure IV-2, for the shortest inter-outcome interval, if the preceding pregnancy ended in a miscarriage or induced abortion, the effect of a short interval on early and late neonatal mortality is substantially smaller. This may occur because the gestation of the preceding pregnancy was shorter and less depleting than the case for preceding live birth outcomes. We also see the effect of a short inter-outcome interval is considerably smaller for stillbirths than for live births (though not as small as it is for miscarriages and abortions). This may occur because for preceding live births there is likely to be an older child "competing" with the index child, whereas this isn't the case

with stillbirths.[5] Also, there is no breastfeeding following a stillbirth. In the models we describe below, we include these interactions between the shortest inter-outcome interval variable (<15 months) and the three types of preceding non-live birth outcomes (abortion, miscarriage, and stillbirth). Our discussions of these models focus on the effects of short intervals that follow a live birth.

Effects of Inter-Outcome Intervals with Other Variables Controlled

We now look at how the effects of inter-outcome intervals change when other explanatory variables are controlled. The results of the Cox proportional hazards models are shown in Appendix Table 3, and the results for inter-outcome intervals are shown graphically in Figures IV-4a-d. The additional explanatory variables are maternal age,[6] parity,[7] month of birth,[8] whether the pregnancy was wanted,[9] residence in the MCH-FP (Treatment) Area,[10] maternal education,[11] paternal education, religion,[12] household space,[13] outcome of the preceding pregnancy,[14] interactions between the indicator for the shortest inter-outcome interval and the outcome of the preceding pregnancy,[15] calendar

[5] We have also investigated this by distinguishing previous live births that are still alive at the beginning of the at-risk period we consider from those who have died, because only those are alive "compete". However, we find a greater effect if the previous child died. We think that this is capturing family-level heterogeneity (mortality risk common across all children born to a woman).

[6] Maternal age is coded as <17 years, 18-19, 20-24, 25-29 (reference), 30-34, and 35 and older.

[7] Birth parity was categorized as 1st birth, 2nd or 3rd birth (reference), 4th –7th birth, and 8th or higher birth.

[8] Each month received its own dummy variable with December set as the reference category.

[9] Unwantedness is a dummy variable with the reference category set as the baby being wanted. This information comes from the RKS, for 84% of the women wantedness is not known. They are coded with their own dichotomous missing-value variable.

[10] Residence is coded as a dichotomous variable where the Treatment Area is coded as 1 and the Comparison Area is coded as 0.

[11] Maternal education and paternal education are coded as 0 years (reference), 1-5 years, 6-10 years, and 11-16 years.

[12] Muslim is the reference category; Hindu or other religion is coded as 1.

[13] Household space is divided into four quartiles, with the lowest quartile (smallest size house) is the reference category. Another dummy variable is added for the houses of unknown size.

[14] Separate dummy variables are included for preceding abortion, preceding miscarriage, and preceding stillbirth; the reference category is for preceding outcome being a live birth.

[15] Our rationale for including preceding pregnancy outcome is described above. We do not, however, include the death of the preceding child by the time of the birth of the index child. We found that if the preceding live birth died before the index child was born, this increased the risk of mortality of the index child, rather than decreasing it, as the sibling competition hypothesis would suggest. I.e., only if the previous child is alive can it "compete" with the index child. Hence, if the competition hypothesis holds, we would expect the effect of a previous interval to be greater if the child born at the beginning of the interval is still alive. The fact that we find the opposite suggests that a previous child death is mainly

year,[16] and subsequent pregnancy and birth.[17] Below we also present models for the MCH-FP Area sample that include some additional variables (breastfeeding and immunization) that we only know women living in that area.

First-Week Mortality

Results for early neonatal mortality, seen in Figure IV-3a, show how the relative risk of mortality during the first week of life varies by inter-outcome interval length, with and without controls for additional potentially confounding factors. The highest risk of mortality during this period is observed for pregnancies following the shortest inter-outcome interval. When only the inter-outcome interval, type of previous outcome, and interaction between previous outcome and the shortest inter-outcome are controlled, the risk associated with the shortest interval where the previous outcome was a live birth[18] is 3.67 ($p<.001$) times the risk of an inter-outcome interval of three-to-five years. When the other explanatory variables that we consider are controlled, infants born after a previous inter-outcome interval of <15 months are 3.03 times more likely to die ($p<.001$) than those whose births were preceded by an inter-outcome interval of three to five years. Hence, though reduced somewhat when other variables are controlled, the risk associated with short intervals remains sizeable and significant. An increased mortality risk remains present at a statistically significant level (32%, $p<.05$) for 15-17-month previous inter-outcome intervals.

Although the results for the other variables are not the focus of this paper, we note that high maternal education is negatively associated with first-week mortality and that

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measuring the fact this family has a higher mortality risk for all of its children. In this case, including an indicator that the previous child died may rob other independent variables of their explanatory power, and we do not include it for this reason. This is better handled through an estimation technique that allows for mother-specific heterogeneity, an approach that we have not yet explored.

[16] We consider five periods of calendar years 1982-1986, 1987-1991, 1992-1996, 1997-1999, and 2000-2002 (reference).

[17] The variables for subsequent birth and pregnancy are considered only during the first through fifth year of life because this is the only time period for which they are relevant. We use the date of the subsequent live birth outcome to create a dichotomous variable indicating whether the woman had had another birth before the beginning of interval (=1) or not. For the subsequent pregnancy, we estimate the date of subsequent conception by subtracting out 274 days from the day of the outcome if it was a live or still birth. If the subsequent outcome was a miscarriage or an abortion, 91 or 61 days were subtracted, respectively.

[18] As noted above, all subsequent discussion of the effect of the shortest interval will deal with the case where the preceding outcome was a live birth.

characteristics associated with significantly higher first-week mortality include short gestation, first birth, young maternal age (<20 years), not being Muslim, being a male child, and unwantedness.

Late Neonatal Mortality

Figure IV-3b shows a striking effect of adding in the controls for the confounding factors when estimating the relative risk of mortality during the late neonatal period (i.e., the second through fourth week of life). The effects of short intervals become smaller when other variables are controlled. Even with these other variables controlled, however, the effects of short inter-outcome intervals remain statistically significant for all lengths of previous inter-outcome intervals shorter than 24 months ($p<.05$) relative to the inter-outcome intervals between three and five years long. The highest risk is again observed for the shortest interval (<15 months). However, even for the babies born after an interval of 24-35 months there is an 18 percent increased risk of mortality ($p=.055$) during the late neonatal period relative to pregnancies preceded by a three-to-five-year interval between outcomes.

The effects of the other explanatory variables are similar to what was observed for first-week mortality model. Again we observe that higher maternal education is protective against late-neonatal mortality. In addition, short gestations, first births, young maternal age (<20 years), a December birth, and not being Muslim are associated with higher risks of mortality during this period. The effect of the pregnancy not being wanted does not persist at the $p<.05$ level during this subperiod.

Post-Neonatal Mortality

As shown in Figure IV-3c, during the post-neonatal period (between the 5th and 52nd week of life), controlling for potentially confounding variables substantially reduces the magnitude of the inter-outcome interval effects. Even with the other variables controlled, however, post-neonatal mortality is higher after short inter-outcome intervals. The highest mortality risk for post-neonatal mortality is for pregnancies following inter-outcome intervals that are shorter than 15 months. The relative risk of post-neonatal mortality for pregnancies that have this short duration of inter-outcome interval relative to an inter-outcome interval of three to five years is 1.80 ($p<.001$). Babies born after an

interval of 15-17 months or 18-23 months experience increased risks of post-neonatal mortality of 78 percent ($p<.001$) and 52 percent ($p<.001$), respectively, relative to those born after a three-to-five-year interval.

During the post-neonatal subperiod, many of the explanatory variables mentioned above still have significant effects on mortality (first birth, maternal age, gestation length, and maternal education). In addition, we observe that household space begins to make a difference, with more household space, which is an indicator of higher socioeconomic status, being associated with a reduced mortality risk. Being born in May or June is also associated with a decreased risk of mortality during the post-neonatal subperiod relative to being born in December. Religion does not have a significant effect on mortality during this subperiod.

Child Mortality

As shown in Figure IV-3d, the controls for the other variables explain all of the higher risk of child mortality at the shortest inter-outcome intervals that is seen when other covariates are not controlled. However, we still observe increased child mortality associated with inter-outcome intervals of 18-23 months and 24-35 months (29%, $p<.01$, and 21%, $p<.01$, respectively) relative to inter-outcome intervals of three to five years.

During childhood, the magnitudes of the effects of inter-outcome interval length, maternal age, and pregnancy duration on mortality are much smaller than in the previous subperiods. This is probably because these are primarily biological variables, whose effects are greatest shortly after birth. Instead, the magnitudes of the effects of socioeconomic factors such as household space and maternal education have increased in size relative to the previous subperiods. Month of birth is unrelated to mortality during this period.

In this subperiod we also observe that the mother being pregnant by the beginning of the subperiod increases the relative risk of mortality of the index child (RR=2.33, $p<.001$). This provides evidence of an effect of a short subsequent interval on the mortality of the index birth. The relative risk of mortality for those who had a subsequent birth is also increased (RR=1.33); however it is not different from 1.0 at a significance level of $p=.10$. There were very few women who had already given birth within one year of having given birth to the index child. Including variables for a subsequent pregnancy

and subsequent birth does not reduce the size of the effect of a short *preceding* intervals on mortality, however. While male newborns have a higher risk of first-week mortality than female newborns, female children have a higher risk of child mortality than male children.

Do the Effects of Reproductive Patterns Vary Across Population Subgroups?

We have explored whether the effects of inter-outcome interval lengths differ among population subgroups. In particular, using interactions, we investigate whether the interval effects differ by the mother's age, parity, time period, maternal education, and whether the mother lives in the MCH-FP Area. We find that the effects of intervals do *not* vary significantly by any of these variables.

In results not presented here, we do find a significant interaction between the effects of maternal age and first parity, though this interaction is only significant during the late-neonatal period. The exponentiated coefficient on the interaction between first parity and the woman's age being at least 30 corresponds to a relative risk of 2.16 ($p<.05$). When multiplied by the large main effect of first parity (RR=1.74, $p<.001$) and the modest (and insignificant) main effect of age greater than 35 (RR=1.05), we see that a woman having a first birth at age 35 or higher has a relative risk of late neonatal mortality of 3.9 relative to a woman in her late 20s having a second or third birth.

How Do the Magnitudes of the Effects of Short Intervals Compare to Those of Other High-Risk Factors?

Another way to assess the importance of pregnancy spacing is to compare the magnitudes of the mortality risks associated with "high-risk" birth intervals to those for other explanatory variables associated with a higher risk of mortality. Pregnancies that follow inter-outcome intervals of less than 15 months have an increased risk of early neonatal mortality that is 3.03 times that of the lowest-risk group (three-to-five-year inter-outcome intervals). By contrast, mothers who are less than 18 years old have an increased risk of first-week mortality of 1.75 times that of the lowest-risk age category (25-29-year-old women). The effects of maternal education and household size are not statistically significant for first-week mortality. In the late neonatal period, the effect of a short inter-outcome interval remains larger than the effects of maternal age and

household size on mortality, but it is not larger than the effect of low maternal education. In the post-neonatal and childhood periods the adverse effects on mortality of little household space and no education are larger in magnitude than the effect of a short interval.

How Does Controlling for Breastfeeding and Immunizations Alter the Estimates of the Effects of Inter-Outcome Intervals?

In the analyses presented above, we were unable to control for breastfeeding and immunizations because these variables were not available for the full DSS sample. To the extent these variables are correlated with inter-outcome intervals, their exclusion may bias the effects of the effects of intervals. For example, women who breastfeed may have longer intervals, and longer breastfeeding itself promotes better infant and child health. Because these variables are only available for the MCH-FP Area and the fact that these variables are time-varying characteristics, we devote this separate section to an analysis of effects of factors that we only know for the MCH-FP Area. In assessing the effects of breastfeeding and immunizations, there is the possibility of reverse causation: Breastfeeding may be short *because* a child died. And a child can only be immunized if he or she lives long enough to be eligible for the immunization. To avoid such reverse causation, we measure each of these variables at the beginning (or before the beginning) of the at-risk period under consideration. Hence, we do not consider the first month of life. But after this, we consider two subperiods of the first year of life and then two subperiods of childhood, so that we can update our explanatory variables.

In modeling the effects of breastfeeding on mortality there is the potential for the mother to stop breastfeeding because the child dies or because the child is ill and about to die, rather than the reverse situation where the cessation of breastfeeding *causes* the death. In an effort to avoid this problem of reverse causality, for each subperiod, we count the number of days the mother breastfeeds up until approximately 90 percent of the start of the interval. This is similar to the approach used by Habicht et al. (1986). As noted above, because we can only consider breastfeeding behavior before the start of the interval, we divided the periods we consider into several smaller subperiods to allow for greater variation in breastfeeding behavior. The four new subperiods of interest are early

post-neonatal (second month to sixth month), late post-neonatal (seventh month to first birthday), early childhood (13^{th}-18^{th} months), and later childhood (19^{th} month until the fifth birthday). There are too few individuals with immunization data during the children's first year of life to include this information in the models until the 13^{th}-18^{th} month-subperiod. The results of these Cox proportional hazards models are in Appendix Tables 4a-d.

Early Post-Neonatal Mortality

For the second month until the sixth month, we estimate two Cox proportional hazards models. The first model includes all of the explanatory variables we included in the full model above. A comparison of this model which only includes the MCH-FP sample to the model using the full sample reveals that the magnitude of the risk of inter-outcome intervals less than 15 months is smaller for the MCH-FP sample (RR=1.93, p<.001) than for the full sample (RR=3.03, p<.001). The direction and general magnitude of the effects of all the other variables are similar. The second model adds an additional continuous variable indicating the number of days that the mother breastfed up until day 25. Since the majority of women breastfeed in Bangladesh, the average number of days of breastfeeding up to and including 25 days is 24.3. For those cases in the MCH-FP Area for which we do not have breastfeeding information (n=1,734), we gave the women an average number of breastfeeding days and included a dummy variable indicating breastfeeding information was missing.[19] The breastfeeding duration variable indicates that there is a strong protective effect of breastfeeding (RR=0.82, p<.001, for each additional day of breastfeeding during this period).[20] The coefficients showing the effect of inter-outcome intervals on mortality, however, do not change much when breastfeeding duration is added into the model. For the shortest inter-outcome interval (<15 months), including breastfeeding days in the model decreases the relative risk of mortality associated with a short inter-outcome interval from 1.93 (p<.001) to 1.90 (p<.001).

[19] Breastfeeding information is missing in the MCH-FP Area for approximately 3.1 percent of the sample.

[20] The coefficient on the breastfeeding unknown variable is very large at RR=8.55 (p<.001). We do not have an explanation for why the 1,734 women in this unknown category have such a high risk of mortality during this subperiod and subsequent sub periods.

Late Post-Neonatal Mortality

For the subperiod between 7 and 12 months (or 183 to 365 days), we estimate the same Cox proportional hazards models as above. This time the second model includes breastfeeding duration up until 165 days after birth and a dummy for unknown breastfeeding duration. For this subperiod, the average number of known days of breastfeeding is 140.8 days.[21]

The baseline model shows that the only intervals that are associated with an increased risk of mortality during this period are inter-outcome intervals of 18-23 months (RR=1.99, $p<.01$) and of 24-35 months (RR=1.59, $p<.05$) relative to an inter-outcome interval of three to five years. The coefficient on the duration of breastfeeding until the 165th day variable is statistically significant, with a RR=0.985 ($p<.001$) per day. However, including the breastfeeding variables barely changes the magnitude of the estimates of the effects of short intervals (which are RR=1.97, $p<.01$ for the 18-23 month interval and RR=1.58, $p<.01$ for the 24-35 month interval when breastfeeding is controlled).

Mortality between 12 and 18 Months of Life

For the subperiod of 366 days until 548 days after birth, we find an increased risk of mortality associated with an inter-outcome interval of 15-to-17 months duration (RR=1.94, $p<.05$) relative to inter-outcome intervals of 36 to 59 months. Adding controls for the duration of breastfeeding up to 328 days and a dummy variable for the duration of breastfeeding being unknown barely alters the relative risk of dying during this subperiod associated with an inter-outcome interval of 15 to 17 months (RR=1.93, $p<.05$ compared to when breastfeeding is not controlled).

The third model we estimate for this time period adds in dichotomous indicators of whether the child had a measles shot by time of his or her first birthday and whether the child had his or her first diphtheria shot by that time. The effects associated with receiving either of these immunizations are not statistically significant at $p<.10$, and adding in these immunization data to the models does not markedly affect the effect of the 15-17 month inter-outcome interval on mortality (RR=1.99, $p<.05$).

Mortality between 1.5 and 5 Year of Age

The final models of this sort that we show are for the period between 549 days and 1,826 days after birth. The baseline model during this time period shows only one inter-outcome interval that is associated with a statistically significant association with mortality: The inter-outcome interval of 60 to 83 months confers a reduced risk of mortality (RR=0.61, $p<.05$) relative to inter-outcome intervals of 36-59 months in duration. For this model, breastfeeding is defined as the number of days the child is breastfed since birth until the 493rd day. The average number of days of breastfeeding for this measure is 390.4. That is, women, on average, breastfeed for longer than a year. As in the other models, for those children with unknown breastfeeding duration, we set their days of breastfeeding to the mean and include a missing-value indicator. Adding in the variables for breastfeeding and immunization do not change the size of the effect of previous inter-outcome intervals by much. During this subperiod, neither the effects of breastfeeding nor of immunizations are statistically significant.

While there are theoretical reasons to expect that controlling for breastfeeding would reduce the "effect" of short intervals on mortality, we do not find empirical evidence to support this. We had a similar expectation that mothers who have short inter-outcome intervals might be less likely to immunize their children, and that controlling for immunizations might reduce the effect of short inter-outcome intervals. In fact, however, there is no significant correlation between inter-outcome interval length and whether the index child had an immunization by the time he or she was 18 months old ($r=.0037$, $p=.23$, for measles immunization and $r=.0018$, $p=.55$, for diphtheria immunization). Thus, the finding that the inclusion of immunization data does not alter the effect of the inter-outcome intervals on mortality is not surprising.

[21] Women with an unknown number of days of breastfeeding were given the average number of days (140.8), and, as above, a dummy variable indicating breastfeeding information was missing was included in the model.

How Does the Duration of the Preceding Interpregnancy Interval Affect Whether that Pregnancy Results in a Live Birth?

To address this question, our measure of the preceding interval is the inter*pregnancy* interval, since the outcome of a pregnancy is directly related to its duration; i.e., pregnancies that end in a miscarriage or abortion are shorter than those that end in a live birth or stillbirth. We estimated a polytomous logistic regression in which pregnancy outcome is the dependent variable. We explain whether a pregnancy ends in an induced abortion, a miscarriage, or a stillbirth; live birth is the reference category. The results of this model are shown in Appendix Table 5, and selected graphical results are shown in Figure IV-5. Relative to a live birth, short interpregnancy intervals are highly associated with a very large increase in the odds ratio of a non-live birth outcome. The odds of having an abortion is 10 ($p<.001$) times that of having a live birth when a woman becomes pregnant within 6 months of a previous pregnancy outcome. This suggests that many of the women who became pregnant within 6 months of a previous pregnancy did not intend to do so and opted for an abortion to terminate the pregnancy. The odds of having a miscarriage or a stillbirth after an interpregnancy interval of less than 6 months are also elevated relative to having a live birth (OR=5.8, $p<.001$ and OR=2.3, $p<.001$, respectively).

Many of the other explanatory variables have statistically significant odds ratios. For example, unwanted pregnancies are 3.95 ($p<.001$) times more likely than wanted pregnancies to end with an induced abortion and 1.56 ($p<.001$) times more likely to end in a miscarriage compared to wanted pregnancies. Other things the same, high parity is associated with a decrease in odds of abortion, miscarriage, and stillbirth, compared to birth parity of 2 or 3. Higher maternal education (1-5 years and 6-10 years) and paternal education (6-10 years) are associated with an increased odds of induced abortion relative to mothers and fathers with no education. Higher maternal education is associated with a decreased odds ratio of miscarriage or stillbirth relative to mothers with no education. With regard to maternal age, abortions are least likely among the women aged 18-19 and 20-24, whereas they are most likely among women who are 35 or more (OR=8.74, $p<.001$) compared to women aged 25-29. Miscarriages and stillbirths are both more common among older women, and have generally decreased over time. Non-Muslim

women are significantly more likely to have an induced abortion (OR=1.35, p<.001) relative to Muslim women. Abortions and miscarriages are both least likely to occur during the month of December.

We find particularly interesting effects of the type of preceding pregnancy outcome. Having had a preceding pregnancy end with an induced abortion increases the risk that the current pregnancy will end with an induced abortion (OR=1.86, p<.001) compared to if the preceding outcome was a live birth. However, if the preceding pregnancy ended in a miscarriage or a stillbirth, the odds that the index pregnancy will end with an induced abortion is reduced by 89% and 79%, respectively (p<.001 for both). This may be due to the fact that women who recently had a non-live birth outcome want to replace their loss. We find that having any preceding non-live birth outcome significantly decreased the risk of having a miscarriage for the index pregnancy. There is a reduction in the odds of having a stillbirth if the preceding pregnancy ended in a miscarriage. Perhaps women who recently had a non-live birth outcome are taking additional precautions not to lose the baby to a miscarriage or stillbirth again.

Influences on Pregnancy Duration

We estimated three OLS regression models in which gestation in weeks is the dependent variable. For these analyses, we use interpregnancy intervals (IPIs) as explanatory variables, rather than inter-outcome intervals (IOIs), because the IOIs include the duration of the pregnancy in the measure, which in this case is our dependent variable. Since we consider IPIs, the sample is restricted to the MCH-FP Area—the one for whom we have high-quality gestation data for a large portion of the sample; 93.7% of pregnancies reported in the MCH-FP Area have known gestation. For the first model, the sample is limited to those pregnancies that resulted in a stillbirth or a live birth. The second model includes only those pregnancies that ended in miscarriage, and the third model includes only those that ended with an induced abortion. The results of these models are shown in Appendix Table 6.

There is a statistically significant relationship between short interpregnancy intervals and gestation for live birth and stillbirths. For inter-pregnancy intervals shorter than 6 months, for example, gestation duration is 0.31 weeks shorter on average (p<.001)

than for pregnancies following 27-to-50-month intervals. For inter-pregnancy intervals between 6 and 8 months in duration, the reduction in gestation is 0.27 weeks ($p<.05$) compared to pregnancies following 27-to-50-month intervals. The magnitudes of these reductions in gestation are not very large, though they are statistically significant. Conde-Aguldo's (2004) systematic review of the literature on the effects of pregnancy intervals on prematurity finds that approximately two-thirds of the studies found an association between short intervals and preterm birth, whereas the remaining one-third of the studies found no association. Other characteristics that relate to pregnancy duration are month of birth (February is associated with longest gestation, and August with the shortest), parity (higher parity decreases gestation duration), maternal education (more education increases gestation), and maternal age (older women have shorter gestation).

For the model that includes only miscarriages, there is no evidence of a relationship between short interpregnancy intervals and the timing of miscarriages. Older maternal age (>34) is associated with a shorter gestation among the miscarried pregnancies, as is a termination date in March or April.

For the sample that includes only pregnancies that end with an induced abortion, interpregnancy intervals between 9 and 14 months are associated with earlier abortions (0.86 weeks less than the pregnancies following intervals of 27 to 50 months, $p<.05$). Surprisingly, for the pregnancies that end in abortion after very short interpregnancy intervals (less than 9 months), there is no difference between the duration of the pregnancy compared to those following intervals of 27 to 50 months. Women with high maternal education (>11 years) have induced abortions that are 2.3 weeks earlier on average than women with no education. This is probably because educated women who have induced abortions in Bangladesh are more likely to use menstrual regulation rather than less safe methods to terminate their pregnancies (DaVanzo et al., 2004). Menstrual regulations (MR) are typically done earlier in a pregnancy than other forms of pregnancy termination because MR is only legal before a pregnancy is clinically confirmed.

How Would Mortality Change If All Intervals Were 3-5 Years Long?

To illustrate the implications of our analyses, we estimate how much lower mortality would be in each subperiod of infancy and childhood if all intervals between

outcomes were 3-5 years in length. We use the full sample of live births controlling for all of the explanatory variables described above and calculate predicted hazards of dying when the population has its actual values and then again when all of the inter-outcome intervals are set to three to five years. We then calculate the ratio of the predicted hazard with the optimal birth spacing and the predicted hazard of dying with the actual values for each individual. The numbers we present in the last column of Table IV-1 are the mean of this ratio subtracted from 1. When all inter-outcome intervals are set to three to five years, the risk of children dying during the first week is reduced by approximately 5.8 percent. A slightly larger effect is found for the other subperiods of infancy and childhood.[22] Conditional on survival during the first week, the risk of mortality during the second to fourth week is reduced by 9.4 percent on average when all intervals are set to three to five years. During the post-neonatal period, if all inter-outcome intervals were 3-5 years, post-neonatal mortality would be reduced by 7.6 percent. Finally, conditional on survival until the end of the first year, mortality during years 1-5 would be reduced by 8.7 percent, on average, if every woman had a an inter-outcome interval between three and five years.

Table IV-1. Summary of simulation exercise in which all inter-outcome intervals are set to between three and five years

Subperiod for mortality (each is conditional on survival to the beginning of the subperiod)	Mean ratio of predicted hazard of dying when all inter-outcome intervals are set to 3-5 years to the actual hazard of dying	% reduction in the risk of mortality
Early Neonatal	.942	5.8%
Late Neonatal	.906	9.4%
Post-neonatal	.924	7.6%
Age 1-5	.913	8.7%

[22] It may seem surprising that the first-week is the subperiod that has the lowest reduction in overall predicted hazard of mortality compared to the other subperiods of infancy and childhood. The reason for this result is that first-week mortality is higher than in the other subperiods when the preceding inter-outcome interval is less than 15 months, which occurs for only a relatively small proportion of the population. A larger proportion of pregnancies have preceding inter-outcome intervals of 18-23 months and 24-35 months. For those intervals, the subperiods of life where the relative risk of mortality is highest are the second to fourth week and ages 1 through 5. These two subperiods are the ones for which we see the largest reductions in mortality when all births are assumed to have a 3-5-year inter-outcome interval preceding them.

Do Differences in Reproductive Patterns between the MCH-FP and Comparison Areas Explain Why Infant and Child Mortality Rates are Lower in the MCH-FP Area?

In Figure IV-6, the line with the triangles shows the relative risks of infant and child mortality for four subperiods of infancy and childhood for the MCH-FP Area vs. the Comparison Area. These are based on hazard models in which an indicator for MCH-FP Area is the only explanatory variable. We can see that the relative risks of infant and child mortality are significantly lower in the MCH-FP Area than in the Comparison Area of Matlab in each subperiod that we consider. During the first week of life, living in the MCH-FP Area reduces the relative risk of mortality by 16 percent ($p<.001$), and during weeks 2-4 the risk of mortality is 37 percent lower ($p<.001$) in the MCH-FP Area. During the remainder of the first year of life and years 1 through 5, the reductions in mortality associated with MCH-FP Area residence are 20 percent ($p<.001$) and 37 percent ($p<.001$), respectively.

We then add controls for the following aspects of reproductive patterns to the hazard model: maternal age, parity, the inter-outcome interval, the type of outcome of the previous pregnancy (i.e., whether a live birth, miscarriage, induced abortion, or stillbirth), an interaction of previous pregnancy outcome with the indicator for the shortest inter-outcome interval, duration of gestation of the index pregnancy, and calendar year. Each of these variables differs between the two areas.

We illustrate this in Table IV-2 for inter-outcome intervals by showing how the distribution of inter-outcome intervals differs between the MCH-FP Area and the Comparison Area. Pregnancies in the Comparison Area are more likely to follow shorter inter-outcome intervals (less than 36 months) than pregnancies in the MCH-FP Area, while longer intervals, of 36 months or more, are likely to occur among women living in the MCH-FP Area. A t-test reveals that the difference between the two percentages is statistically significant ($p<.001$) for all interval-length categories shown. Since, as we have shown in this chapter, shorter intervals are associated with significantly higher risks of infant and child mortality, the difference in the distributions of interval length helps explain the difference in infant and child mortality rates between the two areas that we just saw in the green line (with the triangles).

The relative risks of mortality associated with living in the MCH-FP Area compared to the Comparison Area when we control for all of the reproductive variables mentioned above are shown in the line with the squares in Figure IV-6. Once these controls are added, we cannot reject the null hypothesis at $p<.05$ that the relative risk of mortality associated with living the MCH-FP Area is the same as the relative risk of mortality associated with living in the Comparison Area. This holds true for all four subperiods of infancy and childhood that we investigate. This suggests that the protective effect on infant and child mortality of living in the MCH-FP Area works through altering the reproductive behaviors of the women living in this area.

Table IV-2. Distributions of inter-outcome intervals among live births in the Comparison and MCH-FP Areas of Matlab

	Comparison Area (n=67,165)	MCH-FP Area (n=58,555)
IBI<15 months	0.07	0.05***
IBI: 15-17 months	0.03	0.02***
IBI: 18-23 months	0.08	0.05***
IBI: 24-35 months	0.23	0.14***
IBI: 36-59 months (ref)	0.17	0.20***
IBI: 60-83 months	0.04	0.08***
IBI: 84 plus months	0.02	0.03***

*** Difference is statistically significant at $p<.001$.

Discussion and Conclusions

In this chapter we have shown that preceding short interbirth and inter-outcome intervals are associated with higher levels of infant and child mortality and that these effects, though reduced somewhat, persist when we control for other factors that some researchers have conjectured might explain why such a relationship is found.

While it is true that a short interbirth or inter-outcome interval is more likely when the gestation of the index pregnancy is short and that short gestation itself is associated with higher mortality, the effects of short intervals persist when gestation is controlled. They are somewhat smaller, but they are still substantial and significant.

Controlling for socioeconomic factors also reduces the effect of short intervals, especially in the later subperiods of infancy and childhood that we consider. Nonetheless, the effects of short intervals typically remain when these other variables are controlled. We have in some of our analyses also controlled for breastfeeding and immunizations – variables that have been conjectured to possibly account for the effects of short intervals – and find that, while these variables do indeed affect infant and child mortality, the sizes of the effects of short intervals barely change when these additional variables are controlled.[23] In general, as shown in Appendix 8, the effects of preceding interbirth intervals on neonatal, infant, and child mortality that we estimate for Matlab are very similar to those estimated in analyses of the Demographic and Health Surveys data, such as Rutstein (2003).

The effects of short intervals are strongest in the earliest part of infancy and decline as the child becomes older. For both the early and late neonatal periods, inter-outcome intervals shorter than 15 months are the most pernicious. During the late neonatal period, the effects of short intervals are smaller than they were in the first week of life (both the absolute sizes of the relative risks and their sizes relative to those of other factors), but they are still statistically significant for intervals of less than three years compared to those that are longer. After the first month of life, intervals of less than 18 months are all associated with high post-neonatal mortality; and after the first year of life, intervals of 18-35 months are the most detrimental.

We also find significant negative effects of *subsequent* short interpregnancy intervals on child survival (and we explore this in such a way that it is not subject to the reverse causality that may have biased estimates of this relationship in other studies). We see that a child is much more likely to die during a subperiod of later infancy or childhood if the mother become pregnant before that subperiod. Once this is controlled,

[23] Breastfeeding is nearly universal in Bangladesh. In an effort to avoid reverse causality of breastfeeding being short because children became ill and died, we only consider the duration of breastfeeding up to a short time *before* the at-risk interval under consideration. Nevertheless, it is possible that there is something very different about the types of women with short breastfeeding in Bangladesh. How controlling breastfeeding affects the size of the effects of short intervals should also be investigated in settings where prolonged breastfeeding is not as common.

we do not find, however, that actually having the birth increases the risk of child mortality.[24]

The magnitudes of the risks associated with "high-risk" birth intervals are large compared to those for other explanatory variables associated with a higher risk of infant or child mortality, especially during the first month of life. Babies born less than 15 months after a preceding pregnancy outcome have an increased risk of early neonatal mortality that is 3.0 times that of the lowest-risk group (three-to-five-year inter-outcome intervals). By contrast, for the next highest-risk factor – young maternal age – we find that mothers who are less than 18 years old have an increased risk of first-week mortality of 1.7 relative to the lowest-risk age category (25-29 year old women). In the post-neonatal period and childhood, the adverse effects of low socioeconomic status and no education on mortality are larger in magnitude than the effect of short birth intervals.

We find that inter-outcome intervals are also associated with adverse pregnancy outcomes. Pregnancies that are conceived less than 6 months after the preceding pregnancy outcome are ten times more likely to be aborted, 5.8 times more likely to result in miscarriage, and 2.3 times more likely to be stillborn than those that correspond to an inter-outcome interval of three to five years. The abortion result is particularly striking because it suggests that women care about the spacing of their births and choose more likely to terminate a pregnancy if it occurs too closely after the previous one. This complements the finding in other research on Matlab that pregnancies to women who said earlier that they didn't want more children are much more likely to be aborted (Rahman, DaVanzo, and Razzaque, 2001).

Although there has been increased attention recently to the possible detrimental effects of waiting too long to have the next birth, in this chapter we only see elevated

[24] We have not yet (successfully) investigated the effect of *cumulative* short intervals to see, for example, whether the effect of a short interval is even stronger if the women previously experienced another short interval, especially if it occurred recently. If one of the reasons for the adverse effects of short intervals is maternal depletion, a second short interval might be particularly detrimental. Nor have we done a fixed-effects (or difference-in-difference) analysis where we compare children within a family to their siblings, to see how the survival of those born after very short or very long intervals compares with that of siblings born after medium-length intervals. In concept, such an analysis could enable the netting out of the effects of unobserved factors (e.g., genetics) that are common to all of a woman's pregnancies.

Both of these are very complicated because of the reverse causation that intervals are shorter after a child dies, both because of reduced breastfeeding and also because of an effort to replace the child who

mortality risks for very long intervals (seven years or longer) for early neonatal mortality and only when we consider inter*birth* intervals and do not control for other factors. Hence, long intervals do not appear to carry an additional risk for infants and children. However, as will be seen ahead, long intervals can be associated with adverse outcomes for women.

We don't find any significant differences in the effects of short intervals across population subgroups. I.e., the effects are seen in both areas of Matlab, all age groups, all parities, all years of children's birth, maternal education, and do not vary significantly across these subgroups. We do find, however, that there is a strong interaction between first parity and older woman's age in this population. Children born to women who wait until their thirties to have their first child have a much higher risk of late neonatal mortality. We also see in the next chapter that they have a higher risk of maternal mortality. This may reflect the selectivity of the type of women who don't become pregnant until their thirties, especially in a setting like Matlab where early marriage and a young age at first birth are the norm. Women who have their first pregnancy at an older age may have had difficulty becoming pregnant, and the same factors that contributed to that difficulty might lead to poorer health outcomes for themselves and their children. Such women merit special attention and monitoring.

Our results shed some light on the reasons why short intervals are associated with higher mortality. As noted above, some, but relatively little, of the effect is explained by the fact that shorter interbirth and inter-outcome intervals are associated with shorter gestations of pregnancy. As the child ages, some of the effect of short inter-outcome intervals that is seen in bivariate analyses is explained by socioeconomic factors that are associated with both short intervals and higher risks of mortality.

Our results also give some credence to the maternal depletion hypothesis. We see that short inter-outcome intervals are more detrimental when they follow a live birth or stillbirth than when they follow a preceding miscarriage or abortion. Because of their longer gestation, live births and stillbirths should be more depleting than miscarriages or abortions. The effects of short inter-outcome intervals are greatest when the preceding

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died. A RAND colleague, Arthur van Soest, is doing some work on how to jointly model birthspacing and neonatal mortality that may be relevant to our research.

outcome was a live birth. The breastfeeding that follows a live birth leads to further maternal depletion. Furthermore, if that previous child is still alive at the time of the index child's birth, he or she will compete with the index child for the family's resources – thus lending some support to the competition hypothesis – though we have found the interval effects are greater if the preceding live birth died than if it survived, which is not consistent with the competition hypothesis. The depletion hypothesis is further supported by our finding that effects are greatest for the shortest intervals (which allow the smallest time for recuperation from the previous pregnancy) and in the neonatal period, when physiological factors, such as maternal depletion, are most likely to play a role. The fact that the most pernicious intervals become longer as the child ages is consistent with competition, because children who are 2-3 years older than the index child may be as or more competitive for the family's time and resources as "older" siblings that are even closer in age to the index child.

In the past, health professionals have advocated birth intervals of at least two years in length. Our results are consistent with the findings of recent research (e.g., Conde-Agudelo, 2002; Rutstein, 2003), from both developed and developing countries, that shows that even longer intervals are more beneficial for the health of children and women. Across all of the outcomes that we consider (mortality during various subperiods of infancy and childhood, and whether the pregnancy ended in the non-live birth), the interval length that usually has the lowest risk of adverse outcome is three to five years relative to all shorter intervals. Even for intervals of two to three years, there is an increased risk of late neonatal (18%) and child mortality (21%) relative to children born after intervals of three to five years. Thus, the previously defined desired birth interval of at least two years could arguably be increased to at least three years. Our simulations imply that, even when a large number of mortality correlates are held constant, if all pregnancies followed the previous one by three to five years, mortality rates would be approximately 6-10 percent lower during infancy and childhood.

Our final analysis for this chapter reiterated the importance of improving reproductive patterns for reducing infant and child. That analysis showed that once we control for the differences in reproductive patterns between the MCH-FP and Comparison Areas, there is no additional benefit of living in the MCH-FP area. Thus, it

appears that the success of the comprehensive MCH-FP program in Matlab in reducing infant and child mortality rates is primarily due to in the fact that it has promoted more healthy reproductive behaviors.

Figure IV-1a Interbirth intervals vs. inter-outcome intervals: How length of preceding interval affects **first-week mortality**.
(Numbers come from Appendix 2a; hollow symbols indicate that the relative risk is not different from 1.0 at a significance level of p<.05.)

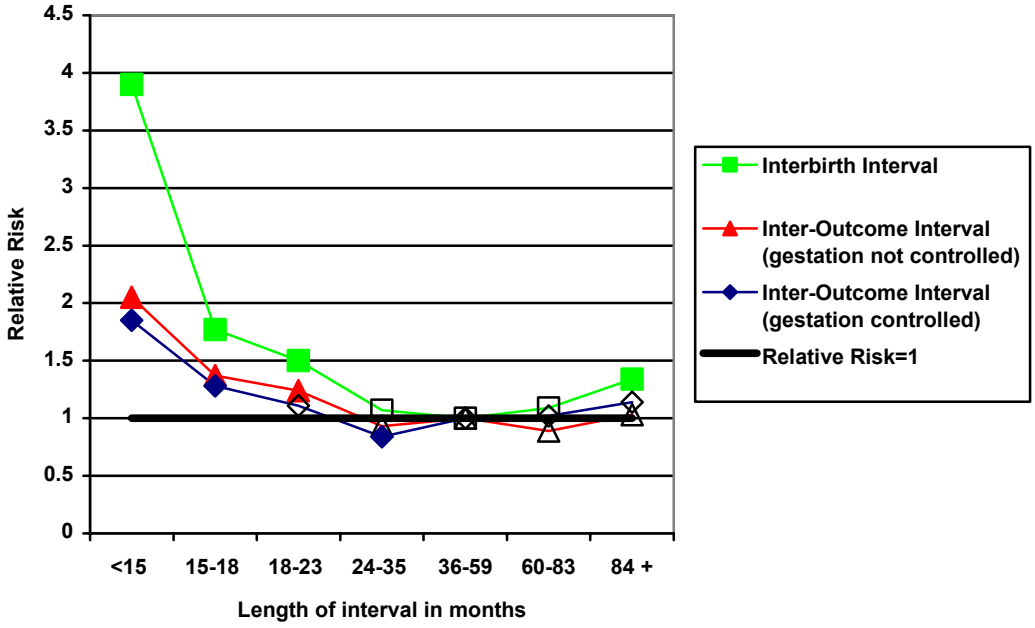


Figure IV-1b Interbirth intervals vs. inter-outcome intervals: How length of preceding interval affects **late neonatal mortality**.
(Numbers come from Appendix 2b; hollow symbols indicate that the relative risk is not different from 1.0 at a significance level of p<.05.)

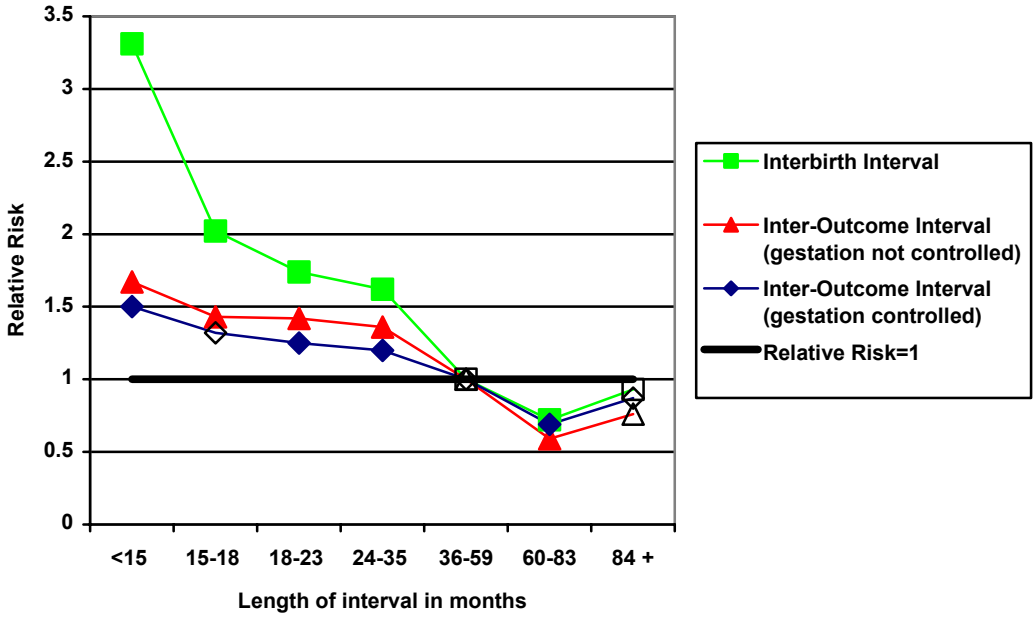


Figure IV-1c Interbirth intervals vs. inter-outcome intervals: How length of preceding interval affects **post-neonatal mortality**.
(Numbers come from Appendix 2c; hollow symbols indicate that the relative risk is not different from 1.0 at a significance level of p<.05.)

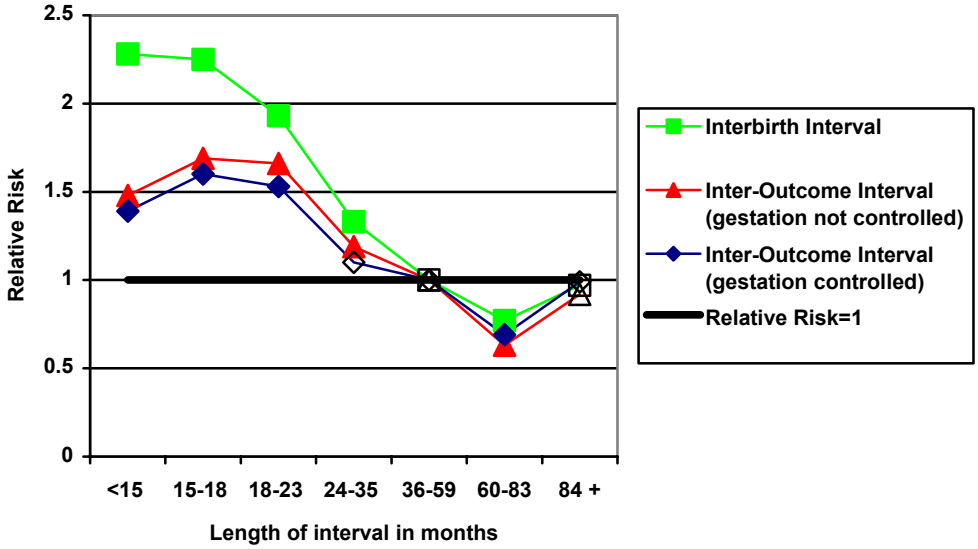


Figure IV-1d Interbirth intervals vs. inter-outcome intervals: How length of preceding interval affects **child mortality**.
(Numbers come from Appendix 2d; hollow symbols indicate that the relative risk is not different from 1.0 at a significance level of p<.05.)

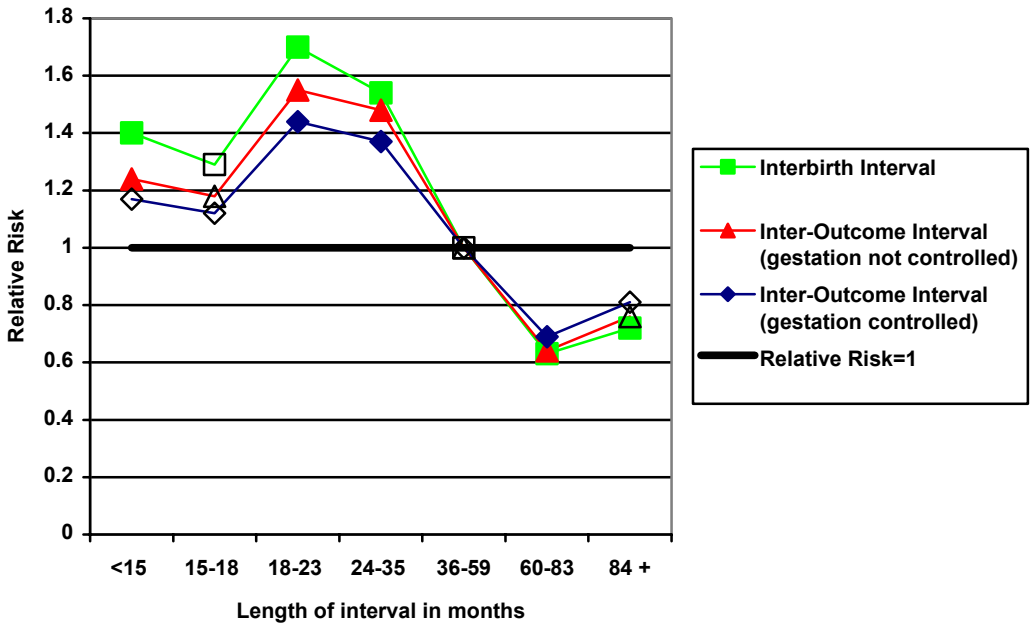


Figure IV-2 Relative risk associated with inter-outcome interval less than 15 months compared to intervals between three and five years for each sub-period of infancy and childhood **by type of outcome of preceding pregnancy**.
(Numbers come from Appendix 2a-d.)

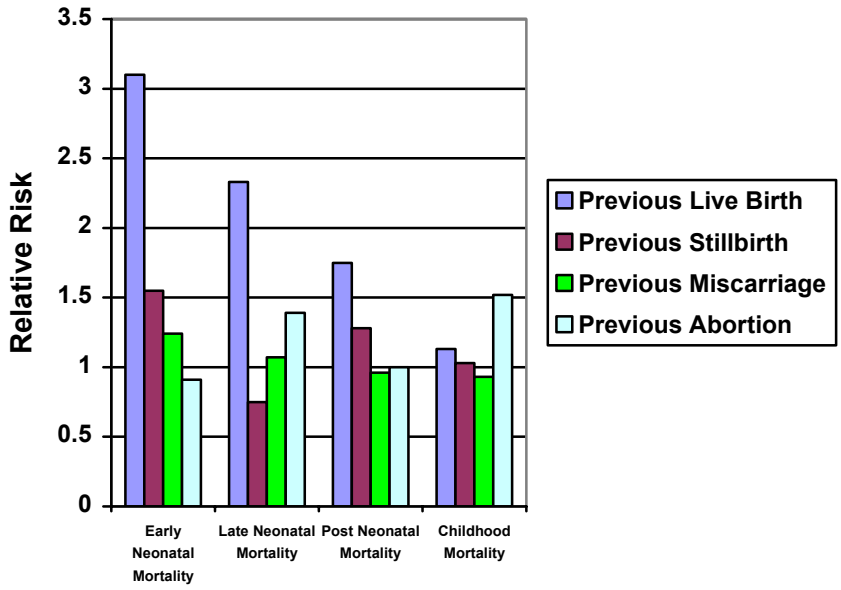


Figure IV-3a How length of preceding inter-outcome interval affects **first-week mortality** without and with controls for other variables.
(Numbers come from Appendix 3a; hollow symbols indicate that the relative risk is not different from 1.0 at a significance level of $p<.05$.)

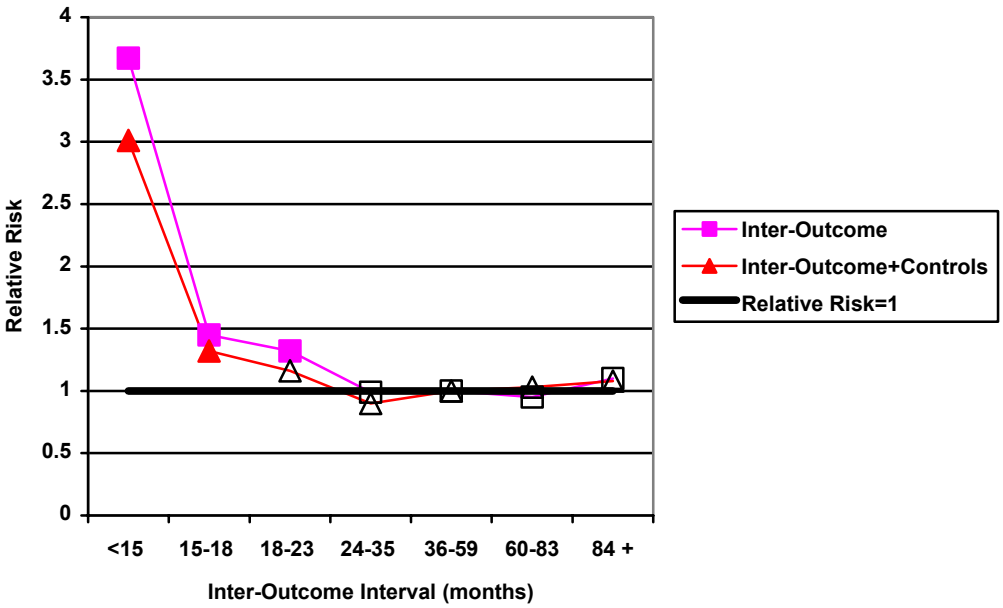


Figure IV-3b How length of preceding inter-outcome interval affects **late neonatal mortality**, without and with controls for other variables.
(Numbers come from Appendix 3b; hollow symbols indicate that the relative risk is not different from 1.0 at significance level of p<.05.)

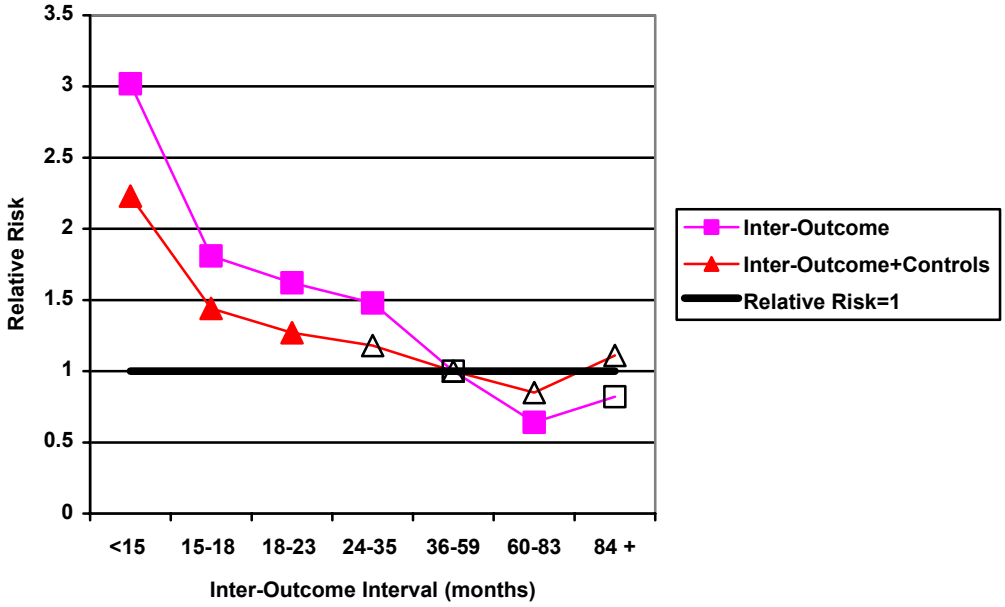


Figure IV-3c How length of preceding inter-outcome interval affects **post-neonatal mortality**, without and with controls for other variables.
(Numbers come from Appendix 3c; hollow symbols indicate that the relative risk is not different from 1.0 at significance level of p<.05).

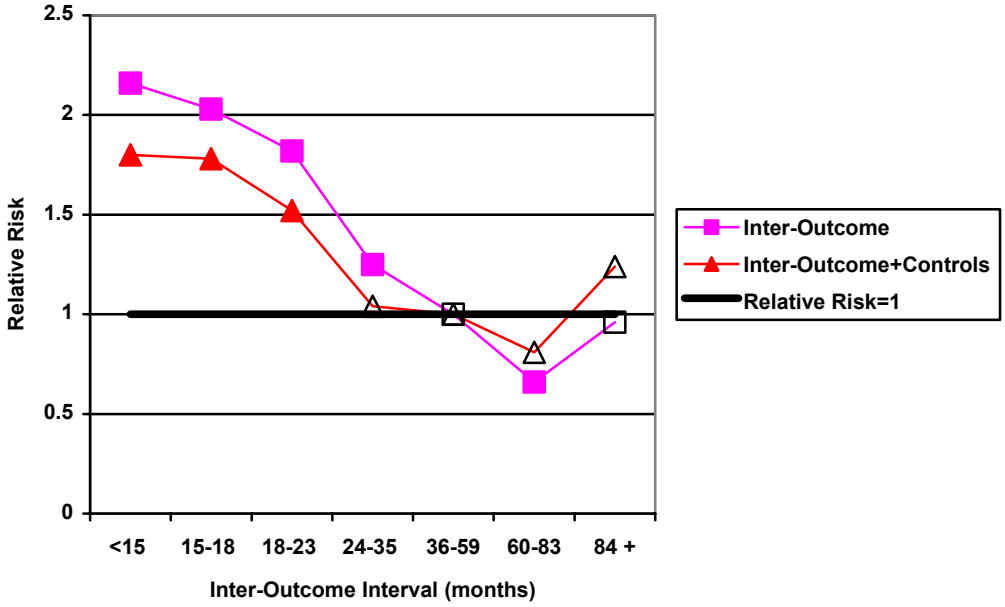


Figure IV-3d How length of preceding inter-outcome interval affects **child mortality**, without and with controls for other variables.
(Numbers come from Appendix 3d; hollow symbols indicate that the relative risk is not different from 1.0 at significance level of p<.05.)

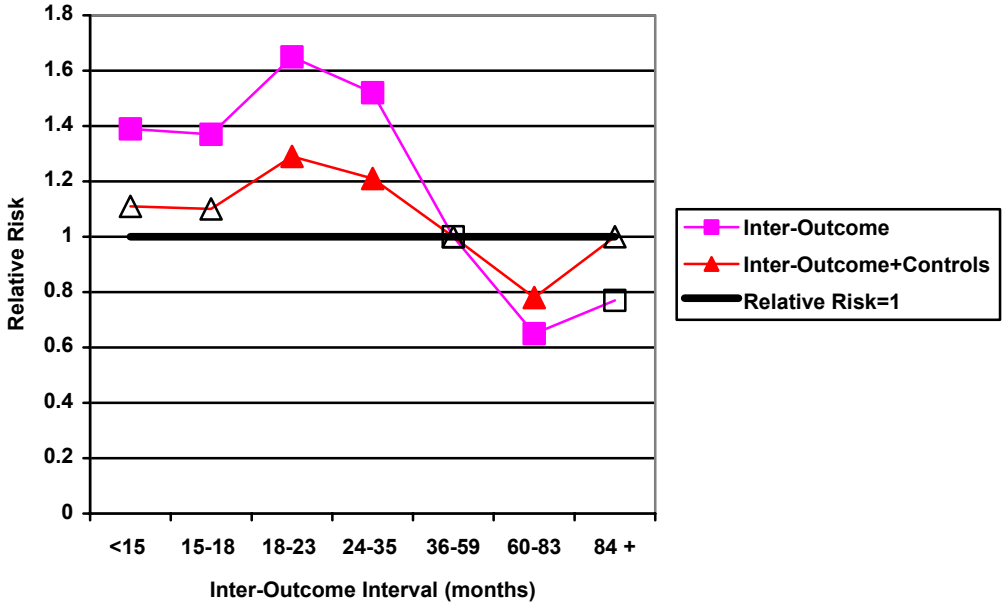


Figure IV-4 Relative magnitudes of the effects of shortest inter-outcome interval length and highest-risk maternal age, maternal education, and housing space on infant and child mortality.
(Numbers come from Appendix 3a-d.)

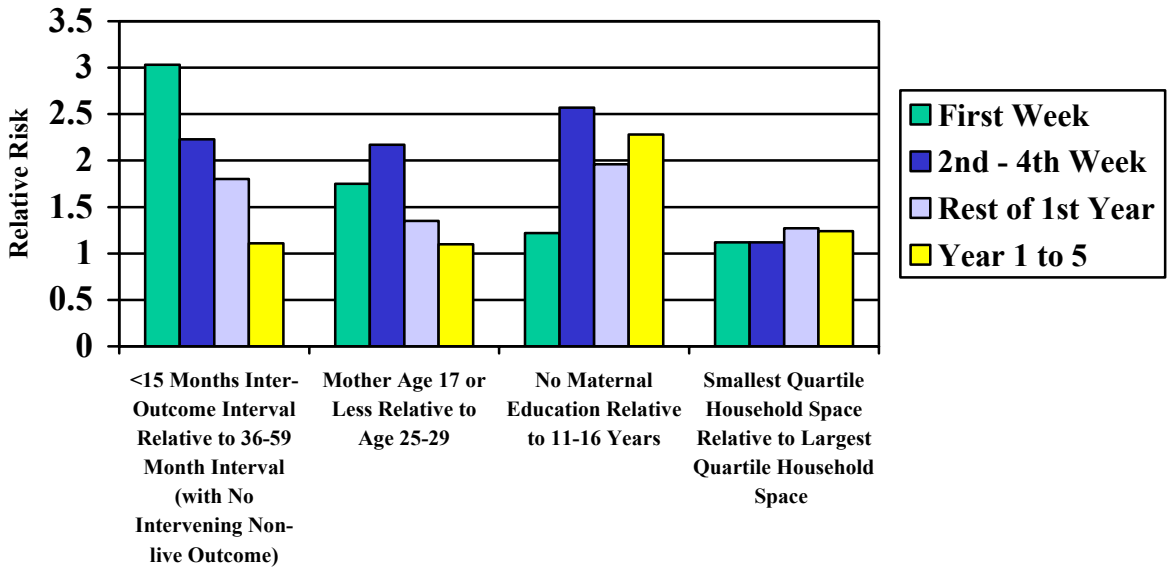


Figure IV-5 Odds Ratios of Effect of Duration of Preceding Interpregnancy Interval on Type of Pregnancy Outcome

(Numbers come from Appendix 5; hollow symbols indicate that the relative risk is not different from 1.0 at significance level of p<.05.)

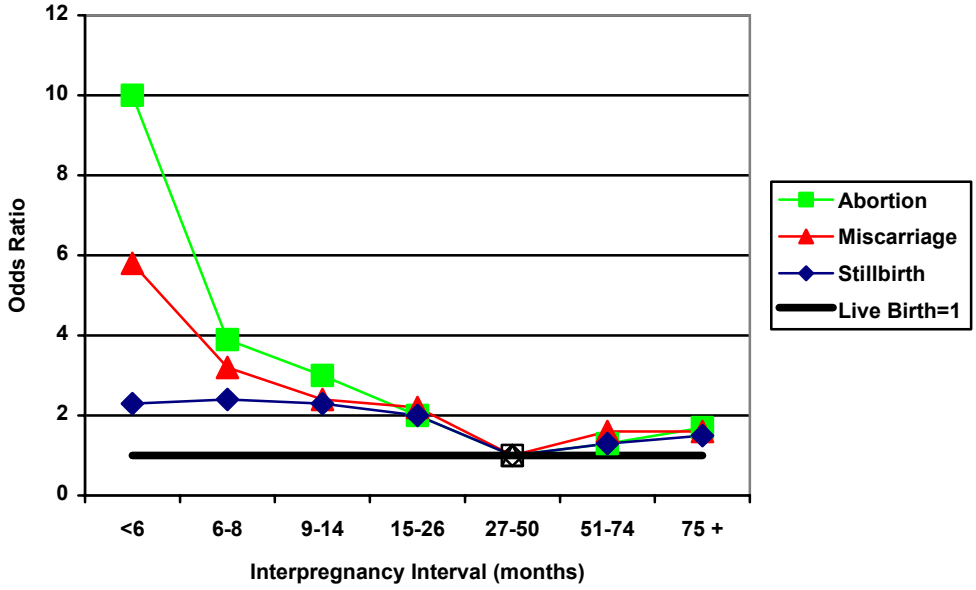
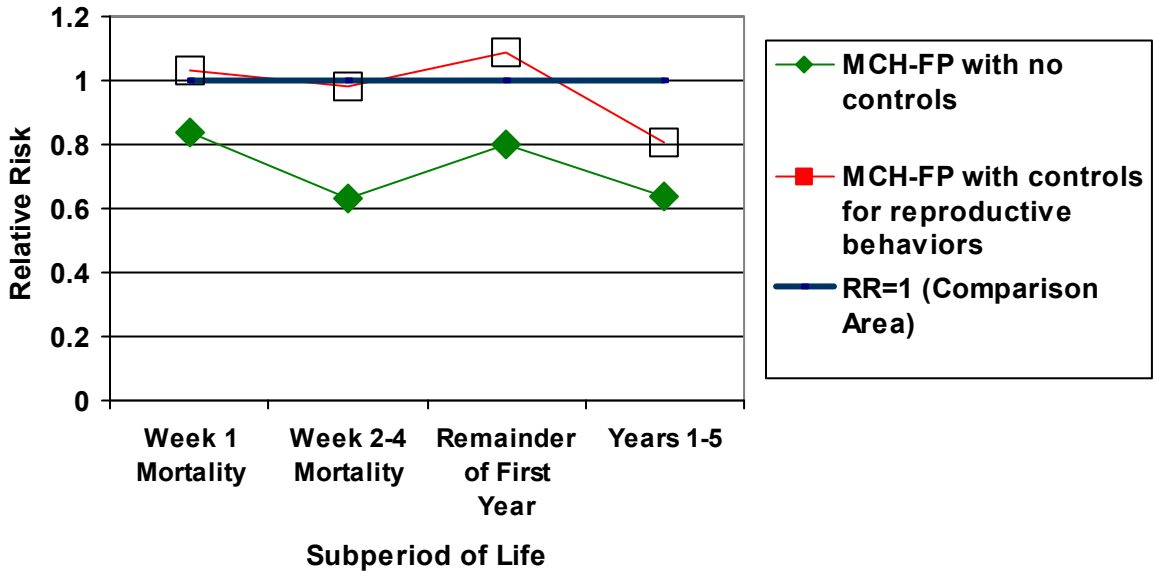


Figure IV-6. The Effect of Living in the MCH-FP Area on Mortality Across Four Subperiods of Infancy and Childhood, with and without Controls for Reproductive Patterns

(Numbers come from Appendix 7; hollow symbols indicate that the relative risk is not different from 1.0 at significance level of p<.05.)



V. EFFECTS OF INTERPREGNANCY INTERVALS, THE MCH-FP PROGRAM, AND SOCIOECONOMIC FACTORS ON MATERNAL MORTALITY IN MATLAB, BANGLADESH

In this chapter, we attempt to address three sets of questions:

1. Is maternal mortality associated with the duration of the preceding interpregnancy interval?
2. Do levels and trends in maternal mortality differ between the Treatment (MCH-FP) and Comparison Areas of Matlab? Is maternal mortality lower in the Treatment (MCH-FP) Area of Matlab than in the Comparison Area? Is maternal mortality in the Treatment Area declining faster than in the Comparison Area?
3. How does maternal mortality vary with socioeconomic factors?

To answer these questions, we conduct both bivariate and multivariate analyses of prospective data from Matlab DSS on nearly 143,000 pregnancy outcomes that occurred during the period 1982-2002.

Background

Interpregnancy Intervals and Maternal Mortality

In the demographic and reproductive health literature it has been asserted that births that are "too" closely spaced carry a risk both for the child's and mother's health (e.g., Khan et al., 1998; Miller, 1991; Winikoff, 1983; and Winkvist et al., 1992). The authors and others propose the maternal depletion hypothesis that argues that it takes a reasonable amount of time for a woman to recover from the physiological stresses associated with the previous pregnancy. Repeated pregnancies in a short period can lead to certain morbidities and nutritional deficiencies that are risk factors for own survival and for their children's health.

It has been clearly shown in many countries that closely spaced births detrimentally affect child health, especially child survival (e.g., Cleland et al., 1984; Rutstein, 2003), and we have shown this for Matlab in the previous chapter. However, it is much less clear whether there is such an effect on maternal health (morbidity and mortality).

Some studies have documented only a bivariate relationship or a gross effect of short intervals on maternal mortality (e.g., Anandalakshmy et al., 1993; Miller et al., 1992; and Winikoff, 1983). It was found that short birth intervals increase the risk of maternal mortality.

Ronsmans and Campbell (1998) conducted a case-control study in Matlab, Bangladesh, to study the relationship between the duration of the interpregnancy interval preceding an index pregnancy (the amount of time between the preceding birth and the conception of the index pregnancy outcome) and maternal mortality associated with that index pregnancy. They use estimated interpregnancy intervals under three different assumptions. They examined all 390 maternal deaths (both from direct obstetric causes and concomitant causes) that occurred during the period 1982-93 and also 1,169 randomly selected controls from pregnancy outcomes in Matlab during this same period.[25] Logistic regressions were used to control not only for the duration of the preceding interpregnancy interval but also for the effects of the woman's age, her education and religion, and her area of residence. Interpregnancy intervals were categorized as <9, 9-14, 15-26, 27-38, and 39 and more months. They found no evidence of a relationship between maternal mortality and the duration of the preceding interpregnancy interval, and concluded that the widespread claim of the pernicious effect of close birthspacing on maternal health in the literature is not substantiated. They recommended that further analyses should consider repeated short intervals, other socioeconomic factors, and other family-formation variables such as child death and pregnancy loss experience. They noted that the confounding effects of these variables could conceal the real effect of short spacing on maternal health. It is possible, however, that their inclusion of maternal deaths due to concomitant causes may have limited their ability to find an effect of birthspacing. We do not include such deaths in our analyses.

Ronsmans and Campbell (1998) did an extensive review of the literature, and found that other studies, too, did not find empirical evidence of effects of birth spacing on maternal mortality. They hypothesize that these studies, too, may have been hampered by not being able to control for the host of confounding variables in operation in the

[25] We don't know whether they included pregnancies that resulted in twins or triplets in their analyses.

relationship between maternal health, family formation, life style, reproductive outcome, and physiological factors which may conceal the real effect of close birth spacing on maternal mortality.

In a recent study, Conde-Agudelo and Belizán (2000) showed that both maternal mortality and some maternal morbidity indicators are significantly associated with the durations of interpregnancy intervals. Maternal mortality was 2.5 times higher among women who had an interpregnancy interval of less than six months (for index pregnancies that last nine months, this corresponds to an interbirth interval of 15 months) than among women having an interpregnancy interval of 18-23. Mortality did not significantly vary for other interval groups. This is the net effect of the duration of the interpregnancy interval after controlling for the effects of maternal age, gravidity, body mass index before pregnancy, history of miscarriage, marital status, education, and smoking habits. Conde-Agudelo and Belizán also find that eclampsia, third-trimester bleeding, premature rupture of membranes, puerperal endometritis, and anemia were significantly higher among women who had an interpregnancy interval of less than six months than for women who had an interval of 18-23 months. These findings support the maternal depletion hypothesis indicated above; both mortality and some measures of morbidity were significantly higher for women who had short interpregnancy intervals. Pre-eclampsia, postpartum hemorrhage, and gestational diabetes mellitus were not associated with short interpregnancy intervals. However, Conde-Agudelo and Belizán find that pre-eclampsia, eclampsia, and third trimester bleeding were higher among women who had an interpregnancy interval of 60 months or longer.

The study by Conde-Agudelo and Belizán has two important features. The sample size is exceptionally large: over half a million women giving live births in 19 countries in Latin America and the Caribbean. However, theirs is a hospital-based study, and the findings may not hold for populations at large, though most of the women in the countries they study do give birth in a hospital. They consider only those women who had live births as the index pregnancy outcome. Also, they only consider the sample of women whose preceding pregnancy (the one right before the index pregnancy) lasted at least 19 weeks. They exclude from their analyses all women whose preceding pregnancy was shorter than that.

Maternal Survival Improvement in Bangladesh: Trends in Maternal Mortality in the MCH-FP and Comparison Areas

The maternal mortality ratio is high in Bangladesh, although it declined from over 5 maternal deaths per 1,000 live births during the 1980s to around 3 per thousand during the late 1990s and 2000-2001 (NIPORT 2002). In Jamalpur and Tangail, two rural areas in the middle-northern region of Bangladesh, maternal mortality ratio was around 6 per 1,000 live births during 1982-83 (Alauddin 1986; Khan et al., 1986). In Matlab, it was between 5 and 7 per 1,000 live births during the late 1960s and early 1970s (Chen et al., 1974) and around 5 per 1,000 during the late 1970s to mid-1980s (Koenig et al., 1988). There has been further decline of maternal mortality to about 3 deaths per 1,000 live births in Matlab in the early 1990s (Maine et al., 1996; Ronsmans et al., 1997). These ratios in Matlab and in Bangladesh are roughly 8-10 times higher than what was found in 19 countries in Latin America and the Caribbean during the late 1990s (Conde-Agudelo and Belizán, 2000). The maternal mortality ratio was about 5 and 0.9 per 1,000 live births during the 1990s in India and Sri Lanka, respectively (www.unicef.org/infobycountry).

It is expected that maternal mortality declines with fertility decline. Such a decline is likely to be associated with various mechanisms of reproductive behavior and activities of reproductive health programs. The Matlab MCH-FP project is an example. It has been successful in increasing contraceptive use, thus reducing fertility, and in increasing child immunization and use of diarrhoeal treatment of children, thus reducing child mortality. The neighboring otherwise-comparable Comparison Area, which receives health and family planning services from the regular government program, experiences higher infant and child mortality and higher fertility than the Treatment Area (ICDDR,B, 2003). Koenig and his colleagues (1988) found a significantly lower maternal mortality *rate*, expressed as deaths per 1,000 women, in the Treatment Area than the Comparison Area during the late 1970s and the first half of the 1980s. They, however, found that the maternal mortality *ratio*, where the denominator is live births, was similar in the two areas. The lower mortality rate in the Treatment Area was a result of the lower birth rate leading to fewer maternal deaths. The maternal mortality ratio more closely measures the risks associated with pregnancies, that is, how likely it is for a

woman to experience maternal death once she is pregnant.[26] This depends on the availability of health services for pregnant women, including delivery facilities that can effectively tackle complications and provide live-saving procedures. During the period considered by Koenig et al. (1988) the Treatment Area did not have different services for deliveries than the Comparison Area.

In subsequent years, maternal mortality declined equally in both areas of Matlab. Maine and her colleagues (1996) and Ronsmans and her colleagues (1997) found that the principal reason for these declines was associated with women's increased utilization of hospitals in a nearby town for delivery and related complications. They found that in recent years more and more women from both areas went to hospitals for delivery, especially in cases of complications. They also found that women from villages close to town or from those villages that have greater transport facilities were more likely to go to hospitals and therefore had reduced their chances of dying during delivery. These villages were both from the Treatment and Comparison Areas. It seems that maternal mortality reduction was associated with the increased institutional deliveries that were nearly equal in the two areas.

In recent years the MCH-FP project has made systematic efforts to increase institutional deliveries in the Treatment Area through their sub-centers that are located in the communities. The Community Health Workers (CHWs) disseminate information to pregnant women on the desirability of antenatal care and of using professional medical services during pregnancy and delivery. Women who come for antenatal care are further counseled to come to ICDDR,B or other delivery centers for delivery and/or whenever they encounter any problems or complications. ICDDR,B data show that institutional deliveries have increased remarkably in the Treatment Area recently. Only a few of the births were delivered in the ICDDR,B sub-centers in the early 1990s. Beginning in 1997 this percentage began increasing, and by 2002 it had increased to over 33 percent. (There are no comparable data for the Comparison Area, but it is expected that it was around 5-10 percent during this same period.) It is expected, for this reason, that we will see a faster decline in maternal mortality in the Treatment Area than in the Comparison Area.

[26] The best measure of this, and the one we consider in our analyses, is to use pregnancies, rather than live births, as the denominator.

Socioeconomic Status and Maternal Mortality

No studies in Bangladesh have attempted to systematically examine the association between maternal mortality and women's socioeconomic characteristics. In the past when health infrastructures were not very developed in rural Bangladesh, when delivery services were not adequately available, when the transportation network was in its infancy, and moreover, when people were not very conscious about availing themselves of institutional facilities for childbirth, we would expect that maternal mortality may not be associated with socioeconomic status. In the last 20 years, however, Bangladesh has made remarkable progress in education, especially women's education, urbanization, and roads and transportation (Caldwell et al., 2000). Increased rural-to-urban movement and migration and mass communication have made people more conscious about using modern facilities for health care. Cash flow has increased with economic improvement associated with more jobs both inside the country and outside. There are more educated women, and men who are more likely to be health conscious.

The 2001 Bangladesh Maternal Health Services and Maternal Mortality Survey (BMHSMMS) cross-tabulated maternal mortality ratio by an economic indicator and by women's education and found no significant association (NIPORT, 2004). However, that study used retrospective data on maternal mortality. One should exercise caution in using such data, since there may be considerable under- or misreporting of deaths. In a study that collected prospective data on pregnancy outcomes and associated mortality over a period of one year in the early 1980s in a rural sub-district of Bangladesh, Alauddin (1986) observed that better-off families tended to have a higher maternal mortality ratio than others.

Methods and Procedures

We analyze maternal mortality for a sample of 145,989 pregnancy outcomes that occurred in Matlab during the period 1982-2002. Our data cover both the Treatment and Comparison Areas of Matlab.

Dependent Variable

Maternal mortality is the dependent variable in this study. We matched death records with the pregnancy outcomes through the unique identification number of DSS. We consider all pregnancy outcomes except those that resulted in multiple outcomes (twins and triplets). We exclude pregnancies that resulted in multiple outcomes mainly because these outcomes carry a special risk of maternal deaths that should be studied separately.[27] There were 3,041 twins and triplets that are excluded.

The cause of death in DSS is classified under the ICD code recommended by the World Health Organization. Through regular DSS activities, each death undergoes a verbal autopsy to identify cause of death. A Health Assistant registers each death in the DSS area in a form and describes the signs and symptoms of the deceased prior to death. Other relevant situations that may be related to the death are also described in the form. Based on the description, a trained medical assistant under the supervision of a committee of physicians classifies the death according to the ICD code. During the process of classification, the medical assistant may send the death form to the Health Assistant to collect further information that may help make a proper diagnosis of the cause of death. Several codes of death are associated with direct or indirect maternal death. This approach of classification of death began in the early to mid-1990s.

A female death during pregnancy or within 42 days of delivery is considered to be a maternal death. Using the ICD classification, we determine whether the death was due to direct or concomitant causes. An example of the former is a death during delivery due to eclampsia, whereas an example of the latter is an accidental death during pregnancy. We consider only direct causes in this study because of our main objective of examination of the relationship between interpregnancy interval and maternal mortality.

[27] We consider 138 women who died during pregnancy. We don't know whether they were carrying multiple fetuses.

In the DSS, there is little likelihood of underreporting of maternal mortality,[28] but there is the possibility of misclassification of cause of death in general and maternal death in particular. We made an effort to see whether there were any misclassifications. A senior project staff member reviewed death forms for all females who were aged 15-49 at the time of death. In order to determine whether a female death is a maternal death, we looked to see if there was a pregnancy outcome or if the deceased was pregnant prior to death. DSS data permit an investigation of these conditions. If one of these conditions was found, descriptions of circumstances of the death and signs and symptoms of associated morbidity were further checked and reviewed to see if the classification was properly done. Following this algorithm, we decided to reclassify the cause of death of 23 deaths from other causes to maternal death. In all, we have a total of 450 maternal deaths, of which 174 died during pregnancy (Table V-1). There were 125,720 live births, 4,310 stillbirths, 8,047 miscarriages, and 4,697 abortions.

The classification of deaths that occurred during 1988-2002 is obtained through the procedure we describe above. Our maternal mortality data for the period 1982 through 1987 come from the study conducted by Koenig and his colleagues (1988). See Koenig et al. (1988) for detailed descriptions of the death classifications used in their study.

The 174 women who died during pregnancy do not have pregnancy outcomes, and therefore these were not recorded as pregnancy outcomes in the DSS. We constructed records for those pregnancies to include in our maternal mortality database. We also collected relevant information on them from various relevant DSS data files.

Table V-1 shows the number of maternal deaths that occurred during pregnancy, 6 days after the end of the pregnancy, and 7-42 days after the end of the pregnancy, separately for deaths due to direct causes and those due to concomitant causes. Our study focuses on the 363 maternal deaths due to direct causes. Of these, 38 percent occurred during the pregnancy, 39 percent within a week of the end of the pregnancy, and 23 percent occurred 7-42 days after the end of the pregnancy. Deaths due to concomitant

[28] It is highly unlikely that the death of an *adult* will not be reported in the Matlab DSS. Death of a DSS resident occurring outside of DSS area is also reported, leaving very little chance of under-reporting deaths.

causes were less likely to occur within a week of the end of the pregnancy and more likely to occur 7-42 days afterward than those due to direct causes.

Independent Variables

The length of the interpregnancy interval preceding the pregnancy outcome under consideration is the variable of main interest in this study. The duration of the interpregnancy interval is the amount of time between the preceding pregnancy outcome and the date of conception of the index pregnancy. This interval can be calculated from DSS data for the entire study period in the Treatment Area but only for the years 2000-2002 in the Comparison Area. The onset of a pregnancy can be estimated from the date of a woman's last menstrual period, which has been recorded as part of women's reproductive history in DSS since 1978 in the Treatment Area and since 2000 in the Comparison Area. In order to include the interpregnancy interval variable for areas all observations, we estimated the interval under certain plausible assumptions. We first calculated the interval between the occurrence of the preceding pregnancy outcome and the occurrence of the index pregnancy outcome (i.e., the inter-outcome interval) for both areas. We then subtracted 8, 7, 4, and 2 months from this interval to estimate the interpregnancy interval for index outcomes of live birth, stillbirth, miscarriage, and abortion, respectively

The number of cases that have missing inter-outcome intervals is fairly large (n=27,076) and represents about 19 and 25 percent, respectively, of all and all non-first pregnancies that are included in the analysis (Table V-2). These cases are mostly from those women who migrated into the DSS area after having one or more pregnancies elsewhere. The DSS does not collect information on the dates of pregnancies that occurred prior to migration. Women whose preceding interval is missing tend to have higher mortality, suggesting a selectivity effect (Table V-2). However, after controlling for the effects other variables in the logistic regression, we find that women with missing intervals do not have significantly higher mortality than others (Table V-7).

In order to see how close the estimated intervals are to the actual intervals, we compared the distributions of estimated and actual intervals in the Treatment Area. The actual duration of the interpregnancy interval is calculated by subtracting the date of

preceding pregnancy outcome from the date of last menstrual period. We found that the distributions of actual and estimated intervals were comparable. We also compared maternal mortality ratios by interpregnancy interval, both for estimated and actual intervals, and found that the ratios are comparable. Furthermore, we estimated a logistic regression equation with all of the explanatory variables shown in Table V-7 and found very similar results. We recognize that women typically conceive two weeks (or more) after the last menstrual period, and hence the date of the last menstrual period is not the same at the date of conception. However, the measure that we use, the amount of time between the preceding pregnancy outcome and the last menstrual period before the conception of the index pregnancy, is the same as that used by Conde-Agudelo and Belizán (2000).

In calculating the interpregnancy interval, we take into account the fact that if the preceding outcome was an induced abortion (which is performed on an average at two months of gestation), the length of the interpregnancy interval following this abortion may not necessarily have an adverse physiological effect on maternal mortality because the women were not pregnant for long. Therefore, if the outcome immediately preceding the index pregnancy was an induced abortion, we calculated the duration of the preceding interpregnancy interval as the amount of time between the index conception and the pregnancy outcome *before* the abortion.[29] We also calculated the interpregnancy interval as the amount of time between the preceding outcome and the index conception, regardless of type of outcome, and we have also conducted the analyses excluding women whose previous outcome was an induced abortion. The effects of interpregnancy intervals on mortality were nearly the same for each of these three approaches.

Methods of Analysis

We examine bivariate variations in maternal mortality per 1,000 pregnancies by the duration of the interpregnancy interval, woman's age, her gravidity, her experiences of child death and pregnancy loss (through abortion, miscarriage, or stillbirth) prior to this pregnancy, her education, household space as indicator of economic conditions, religion, and for four time periods – 1982-87, 1988-92, 1993-97, and 1998-2002. We

[29] Conde-Agudelo and Belizán (2000) also are concerned about this issue. They *exclude* from their analyses women whose preceding pregnancy lasted less than 20 weeks.

then estimate a logistic model to see if the relationships of these variables with maternal mortality changes when the others are controlled.

The categorization of interpregnancy intervals that we analyze is based on the following two considerations: (1) We want to compare our maternal mortality results with those of Conde-Agudelo and Belizán (2000); and (2) we want our categories to be comparable with commonly used inter*birth* intervals such as less than two years, 2-3 years, 3-5 years, and more than five years.

Results

Bivariate Analyses

Table V-2 and Figure V-1 show the likelihood that a pregnancy will end in a maternal death by the duration of the preceding interpregnancy interval. Table V-2 also shows this likelihood for first pregnancies. There is a U-shaped relationship between maternal mortality and the duration of the interpregnancy interval. The lowest probability of maternal mortality is observed for the 27-50-month interpregnancy intervals (which, for full-term pregnancies, corresponds to an interbirth interval of 36-59 months, or 3-5 years). Compared to interpregnancy intervals of 27-50 months, risks of maternal mortality are higher for interpregnancy intervals shorter than 27 months, especially for those with intervals less than 6 months. For example, the odds of mortality is 58 percent higher among women who had a conception within six months of the last pregnancy outcome compared to women who conceived after a period of 27-50 months; however, this difference is not statistically significant. Mortality risks are also higher, in fact the risk is the highest of all interval lengths we consider, for very long intervals. The mortality risk is more than double for women who waited for more than 75 months after the previous pregnancy outcome to conceive again (which corresponds to a birth interval of more than seven years for full-term pregnancies) compared to women with an interpregnancy interval of 27-50 months. This difference is statistically significant ($p<0.05$). We also observe that mortality risks are higher for first pregnancies ($p<0.001$) and for women whose previous interval length is unknown ($p<0.001$) than for women with two or more pregnancies and an interval of 27-50 months.

Conde-Agudelo and Belizán (2000) also observed a harmful effect of long intervals on maternal morbidity (pre-eclampsia and eclampsia) but not on maternal mortality. In interpreting such an association, they comment that the physiology of a woman having pregnancy after a long interval seems to behave like that of a woman who is pregnant for the first time. In our data the risks of mortality are indeed very similar for women with the first pregnancies (3.66 maternal deaths/1,000 pregnancies) and those whose pregnancies are preceded by an interval of 75 months or more (3.83/1,000).

In Table V-3 we examine mortality rates cross-tabulated by mother's age *and* gravidity. (Total number of cases is smaller in Table 3 than in Table 2 because of missing values.) Such an examination can indicate the influence of repeated pregnancies in short intervals. Consistent with previous studies in Matlab and Bangladesh, we see that both age and gravidity have a U-shaped relationship with maternal mortality.

Women with first pregnancies had higher mortality risks regardless of age than women with higher-order pregnancies. Ages 20-24 seem to be safest ones to have the first pregnancy in Matlab, in that the risk of maternal mortality is lowest for this age group. Holding constant gravidity, the risk of maternal mortality generally increases with age beyond age 29. This is especially true for first pregnancies. Women who don't have their first pregnancy until their 30s or 40s may have health problems that both made it more difficult to conceive and increased their risk of maternal mortality. For first pregnancies, teenagers also have higher risks of mortality than women aged 20-29. In the marginals by age, we do see higher risks for teenagers, but these seems to largely reflect the effect of age for first pregnancies as well as the fact that teenagers have a higher incidence of first pregnancies (which have a higher risk of maternal mortality) than older women.

Comparing mortality rates for different gravidities within the same age group may yield insights about the effects of pregnancy spacing. For example, for women aged 25-29, pregnancies will be more closely spaced for women who have 7-8 pregnancies than for those who have 5-6 pregnancies if they began childbearing at the same age. In almost all age groups, there is a tendency for mortality to increase with gravidity, though the rate of increase is not large. This relationship is consistent with the relationship we observe in

Table V-2 between the duration of the interpregnancy interval and the likelihood of maternal mortality.

In Table V-4, we examine the relationship between maternal mortality and a woman's previous experience of child deaths and pregnancy loss. These variables are likely to be correlated with a woman's own health status, her health-related behavior, family environment, and others aspects that influence the overall health of a woman and her children. We observe in the table that both prior child deaths and pregnancy loss are risk factors for maternal mortality. The likelihood of maternal mortality was 35 percent ($p<0.05$) and 83 percent ($p<0.01$) higher among women who had one and two or more child deaths, respectively, prior to the index pregnancy compared with those with none. Maternal mortality was nearly 60 percent higher ($p<0.05$) among women who had two or more prior pregnancy losses through miscarriage, stillbirths, or abortion compared to women with no previous pregnancy losses. Women with only one pregnancy loss do not seem to have higher risk of mortality than those with no previous pregnancy losses.

In Table V-5, we observe that maternal mortality is negatively associated with the woman's and her husband's education and with their household space. Women who have 1-5 years of schooling have a 20 percent lower mortality risk than their counterparts with no schooling ($p<0.10$). Women with 6-10 years and 11 or more years of schooling had 45 percent ($p<0.05$) and 43 percent (NS) lower risks of mortality, respectively, than women with no schooling. Similarly, women had 29, 40, and 43 percent lower risks of mortality, respectively, if their husbands have 1-5 years or 6-10 years, or 11 or more years of schooling compared to women whose husbands have no schooling. These differences in mortality are significant at the 1%, 1%, and 10% levels, respectively. Women from the "High" household-space group had 35 percent lower mortality than those in the "Low" group ($p<0.05$). Mortality in other household-space groups was similar to that in "Low" group. Non-Muslims, who are mostly Hindu, had slightly but insignificantly higher (7%) mortality than Muslims.

Table V-6 and Figure V-2 show that the risk of maternal mortality is always lower in the Treatment Area of Matlab than in the Comparison Area, and that mortality has generally declined in both areas, but the decline is faster in the Treatment Area, especially in the more recent years that we consider. In regards to differences between

two areas, risks of maternal mortality were 21-25 percent lower in the Treatment Area than the Comparison Area during the period 1982-1997. During the later period of 1998-2002, mortality risk was 43 percent lower in the Treatment Area than Comparison Area.

In both areas, over the 1982-2002 period that we consider we see the highest probability of maternal mortality in 1982-87 and the lowest in 1998-2002 (Table V-6 and Figure V-2). This difference is significant at the 0.001 level. However, in both areas, maternal mortality is higher in 1993-97 than in 1988-92, but the difference was not significant. The increase in maternal mortality between the 1988-92 and 1993-97 periods may be due to an improvement in the classification of maternal deaths around 1993 (which was mentioned above in the Methods section).

Multivariate Analyses

Table V-7 shows odds ratio estimates from our logistic regression analysis. When the other explanatory variables that we consider are controlled, we do not find any evidence that women are at significantly higher risk of mortality following a short interpregnancy interval. The risks associated with shorter intervals seen earlier in Table V-2 are each reduced somewhat when other explanatory variables are controlled. However, women with interpregnancy intervals of 75 months or more (which, for full-term pregnancies, correspond to interbirth intervals of seven years or more) have more than two times risk ($p< 0.05$) of maternal mortality compared to those with interpregnancy intervals of 27-50 months. The differences between our estimates of the effects of intervals with and without controls are illustrated in Figure V-3. We explored whether the effects of intervals on maternal mortality varied between the MCH-FP and Comparison Areas or by age, education, and the other explanatory variables that we consider, but we did not find any significant interactions.

Maternal mortality is generally positively associated with the woman's age after age 24. The risk of maternal mortality is significantly greater for women aged 25 and older compared to those aged 20-24, and this risk increases especially after age 30. There is no evidence that teenagers have higher risks of maternal mortality than their older counterparts. As mentioned above, the higher mortality observed among teenagers in the bivariate analysis largely reflects the fact that first pregnancies that have high risks of mortality, and most of the pregnancies that occur before age 20 are first pregnancies.

(For example, in our data, 77, 33, and 6 percent of pregnancies were first pregnancies in age groups <20, 20-24, and 25-29, respectively.) After controlling for the effects gravidity and other variables, we see that teenagers and 20-24-year old women have similar mortality risks. This finding does not support the commonly believed hypothesis that having a birth before the age of 20 years puts a woman at the risk of her own life.

In the bivariate analysis, mortality risks steadily increase with gravidity, especially after the third pregnancy. Within an age group, we also observe similar results. The multivariate regression results of the gravidity-mortality relationship are puzzling because mortality risk decreases with gravidity, and women with eight or more previous pregnancies are likely to have significantly lower risk of mortality than others (Table V-7). The common belief is that mortality would increase with gravidity. There weren't strong effects of high gravidity in Table V-3 either. It may be that high gravidity is associated with other variables that we control in Table V-7. One interpretation of observed gravidity and maternal mortality relationship is that healthier women who have lower risks of mortality are likely to be more fecund and to have higher number of pregnancies. This is a standard reverse-causality explanation of the relationship.

We find even stronger effects of prior child deaths and pregnancy losses in the logistic regression than in the bivariate analysis. Women who lost one and two or more children to death had 64 and 83 percent higher risks of maternal mortality, respectively, than those women whose children did not die. Again, women who had lost one pregnancy or two or more pregnancies through abortion, miscarriage, or stillbirth had 28 (not significant) and 91 percent ($p<.01$) higher risks of mortality than those women who did not have a previous pregnancy loss. As we mention above, these two variables might reflect the effects general health conditions of the mother influenced by her personal, family, and environmental circumstances.

Woman's education has been found in other studies to be a strong determinant of many different measures of health behavior and health outcomes. We find here that a woman's education and her risk of maternal mortality are negatively associated. In the bivariate associations in Table V-5, the odds ratios of maternal mortality decline nearly monotonically as education increases. In the multivariate analyses (Table V-7), however, we observe a significant association only at 10% level and only for the education

category 6-10 years of schooling. In results not reported here, women's education is negatively and significantly ($p<0.05$) associated with maternal mortality when entered as a continuous variable in the logistic regression otherwise like those shown in Table V-7. We observe a four-percent reduction of mortality for each year of schooling.

Discussion

We analyze prospective data from Matlab DSS on maternal mortality among a large number of pregnancies during 1982-2002 to investigate the relationship between the length of the interpregnancy interval that precedes an index pregnancy and maternal mortality associated with that pregnancy. We use DSS records on pregnancy outcomes to construct measures of interpregnancy intervals and maternal mortality. Our data on the latter are unlikely to suffer from the underreporting usually encountered in data on maternal mortality. Also, our data on maternal mortality, coming from frequent prospective data collection in an entire population, rather than, say, only deaths occurring in a hospital or relatives' reports of women's deaths, are likely to cover a more representative sample than those used in many previous studies. The sample size is also large. Our study has more deaths than Conde-Agudelo and Belizán (2000) have in their study of over half a million live-birth deliveries in Latin America and the Caribbean.

We find suggestive evidence, based on bivariate analysis, that there may be a relationship between interpregnancy interval and maternal mortality. A woman with interpregnancy intervals of less than six months (equivalent to an interbirth interval of less than 15 months for full-term pregnancies) has around a 60 percent greater chance (statistically insignificant) of maternal mortality than a woman with an interpregnancy interval of 27-50 months (which, for full-term pregnancies, corresponds to an interbirth interval of 36-59 months, or 3-5 years). This greater risk, however, reduces to 30 percent (statistically insignificant) when we control for the effects of demographic, socioeconomic, and programmatic variables. This finding of no significant relationship between short intervals and maternal mortality is consistent with that found in Matlab by Ronsmans and Campbell (1998), who did a case-control study and controlled the effects of other relevant variables.

We find that an interpregnancy interval of 75 months or longer (equivalent to an interbirth interval of seven or more years for full-term pregnancies) is pernicious to maternal health. Maternal mortality is two times higher for such long intervals compared to interpregnancy intervals of 27 to 50 months. The higher risk of maternal mortality we find for such very long intervals is consistent with Conde-Agudelo and Belizán's (2000) finding that such intervals are associated with higher levels of pre-eclampsia, eclampsia, and third-trimester bleeding. The analyses of maternal morbidity presented in the next chapter of this report show that the incidence of pre-eclampsia and high blood pressure is around two times (and significantly) higher among women with interpregnancy intervals of 75 or more months than those women with 27-50 month intervals. Based on this result, a message to a woman who has already been pregnant before and wants to be pregnant again may be that, for the sake of her own health, she should not wait for more than six years to become pregnant again.

However, it is possible that this effect is not really a causal effect of long intervals, but instead that a long interval is itself a reflection of poor maternal health. A woman in poor health may have difficulty becoming pregnant, and this may lead to a very long interpregnancy interval. The incidences of malnutrition, anemia, reproductive tract infections, and other maternal morbidities, alone or in combination with other illnesses, are high in Bangladesh, as they are in many developing countries. It is quite possible that women with these conditions develop sub-fecundity, and thus those women who want to have an additional child may take a long time to conceive. We find that morbidity incidence was high among women with very long intervals, supporting our hypothesis. Some studies (not ours, however) have observed an elevated risk of infant and child mortality for such long intervals. This might also be explained by such a health-effect mechanism. In our data, three percent pregnancies were with such long interval of 75 or more months, or seven years of equivalent interbirth interval. Further research is needed to see if there is a relationship between long interpregnancy intervals and health conditions.

Maternal mortality risk is similar among teenagers and women aged 20-24 years, once the effects of gravidity and other variables are controlled for. It is widely believed in the field of reproductive health that teenage motherhood is detrimental to childbearing

including maternal mortality and infant and child mortality. With prospective good-quality data with large sample size, we find that this not the case for maternal mortality in Matlab. Our infant and child mortality analyses show that the detrimental effect of teenage motherhood is limited to the first year of a child's life.

Maternal mortality risk increases sharply with age after age 30 and thus our findings strongly suggest that being "too old to have a birth" is detrimental to maternal survival. This has strong programmatic implications in Bangladesh. Because of early marriage and childbearing, most women achieve their desired family size, which averages 2.5 children, before age 30. During the ages 30-49, women on average end up with about one excess child. This is mainly due to inadequate accessibility to contraception. Contraceptive method choice in Bangladesh is heavily skewed towards spacing methods such as pills, injectables, and condoms and traditional methods. Women who have already achieved their desired family size continue to use these spacing methods, which have high rates of use-failure and/or discontinuation associated with side effects. Permanent contraceptive methods or longer-term methods that are appropriate for limiting fertility are, unfortunately, not popular in Bangladesh. Many women thus encounter unintended pregnancies. Some abort their pregnancies, and others end up with a live birth leading to excess births. In other research, we show that abortion sharply increases with a women's age (Rahman, DaVanzo, and Razzaque, 2004). Strong family planning behavioral change communication (BCC) activities coupled with quality services should be designed to have a balanced contraceptive method mix in which more and more couples will adopt permanent and longer-term methods for limiting purposes. This can help reduce the incidence of childbearing beyond age 30 and thus reduce maternal mortality.

There is, however, a group of women who, because of poor health and adverse circumstances, find it difficult to become pregnant and then have a live birth. They continue to try to conceive in the hope of having children. We gave an example above of how women may have very long birth interval associated with poor health. These women need help from health programs.

We do not find any evidence that the risk of mortality increases with gravidity. This does not support the popular belief that having too many children is a risk factor for

maternal mortality. Together, our findings do not support the popular understanding that too young motherhood, too short a birth interval, or too many pregnancies are detrimental to maternal health. We do find that first pregnancies carry an extra health risk for both mothers and children. For mothers and the late neonatal period of infancy, this is especially true for older women. Older women who are pregnant for the first time should be carefully monitored.

We find, like previous studies, that maternal mortality has been declining in Matlab. Previous studies found that the decline was similar in Treatment and Comparison Areas. We find with data from more recent years that the decline in maternal mortality has been greater in the Treatment than in the Comparison Area in more recent years. This greater decline in the Treatment Area is associated with greater use of hospital services for delivery during this period. As mentioned above, over one-third of deliveries in the Treatment Area took place in ICDDR,B hospitals, which can tackle complications, provide caesarian sections, and have a strong referral system to higher-level facilities. In contrast, hospital delivery continues to be less common in the Comparison Area. An implication is that institutional deliveries should be promoted to reduce maternal mortality in Bangladesh. Bangladesh has a large government-managed health infrastructure. The infrastructure includes many facilities that provide deliveries and are well equipped to manage pregnancy complications and perform caesarian sections. All 64 districts of the country have emergency obstetric care facilities; there are a number of other special facilities for emergency obstetric care; and there are a number of teaching hospitals. There are over 400 Thana Health Complexes at the sub-district level that provide delivery and complications management but do not have facilities for doing caesarian sections. However, there is a system of referral from the sub-district to district level that inhibits use of these facilities. Numerous private clinics have been established in recent years around the country that provide deliveries including caesarian sections. Unfortunately, less than 10 percent of deliveries in Bangladesh take place in such facilities, and many facilities are underutilized. A strong behavior change communication (BCC) program can promote the idea of giving birth at a hospital. People now have greater mobility between villages and towns; road network and transport have greatly increased; health consciousness is steadily increasing through increased education

and mass media; women's education is dramatically increasing; and, moreover, economic conditions are steadily improving. All these can work synergistically to increase institutional deliveries in Bangladesh if an appropriate BCC program can be launched effectively. In rural Bangladesh, some NGOs undertook innovative BCC approaches by raising community awareness on the need of institutional deliveries, facilitating community funds to cover hospital costs, and by arranging for the transportation of pregnant women to hospitals. This has increased institutional deliveries of complicated cases. The NGO Service Delivery Program's partner NGOs that provide essential health services are replicating these approaches in their catchment communities.

We find that maternal education and socioeconomic conditions have a statistically significant effect on maternal mortality. This is a new finding in Bangladesh. No previous studies found such a significant relationship. The explanation of no effect of socioeconomic condition on maternal mortality in the past may be the following: In the past, even if people from higher socioeconomic groups wanted to have institutional deliveries, they could not have them because of unavailability of facilities or lack of transportation to go to facilities. The situations have noticeably improved in recent years. We find that women who are educated, or whose husbands are educated, or women from richer families are now less likely to die from pregnancy or childbirth Socioeconomic conditions, especially the education of women, are improving rapidly. It is expected maternal mortality will continue to further decline due to socioeconomic improvement. BCC activities can help to increase women's understanding of the benefits of institutional deliveries.

Greater utilization of maternal health services by the more advantaged groups is likely to increase the inequality of health conditions even further. An effective safety-net system for improving the health of the poor and the illiterate is needed to help sustain maternal mortality reduction. The Bangladesh government, for example, is currently reviewing a scheme that will distribute maternity vouchers that would enable poor women to have deliveries at hospitals (MOHFW 2004). Implementation of such a scheme through carefully designed and well-supervised management system should help reduce the high-levels of maternal mortality in Bangladesh.

Table V-1. Direct and concomitant maternal deaths by time of occurrence, Matlab, 1982-2002

Time of death	Direct causes		Concomitant causes		Total	
	Number	Percent	Number	Percent	Number	Percent
During pregnancy	138	38.0	36	41.4	174	38.7
0-6 days after end of pregnancy	143	39.4	15	17.2	158	35.1
7-42 days after end of pregnancy	82	22.6	36	41.4	118	26.2
Total	363	100.0	87	100.0	450	100.0

Table V-2. Probability of maternal death (deaths per 1,000 pregnancies) by the duration of the preceding interpregnancy interval, Matlab, 1982-2002

Interval	Probability	Odds ratio	Number of pregnancies
First pregnancy	3.66	2.22	33,335
<6 months	2.60	1.58	4,228
6-14	1.80	1.09	11,116
15-26	1.86	1.13	25,824
27-50 (RC)	1.65	1.00	27,875
51-74	1.77	1.07	9,057
75+	3.83	2.32**	4,437
Missing interval	3.07	1.86**	27,076
All	2.54	--	142,948

RC = Reference category for the odds ratios.

**=p<0.01, ***=p<0.001 (tests of the significance of the difference from the reference category)

Table V-3. Probability of maternal death (deaths per 1,000 pregnancies) by age and gravidity, Matlab, 1982-2002

Age	Gravidity									
	1	**2**	**3**	**4**	**5-6**	**7-8**	**9-10**	**11+**	**Total**	**Odds ratio**
<18	3.88 (4,903)	1.59 (628)	0.00 (117)	(24)	(7)				3.52 (5,679)	1.84*
18-19	4.36 (9,854)	1.03 (2,912)	1.86 (538)	0.00 (115)	(34)	(4)	(1)		3.49 (13,458)	1.83**
20-24	2.76 (15,607)	1.84 (16,858)	1.06 (9,450)	0.55 (3,612)	2.86 (1,399)	0.00 (100)	(6)		1.91 (47,032)	1.00
25-29	4.16 (2,401)	1.41 (6,402)	1.02 (9,794)	1.23 (8,934)	2.38 (8,810)	3.36 (1,487)	0.00 (151)	(18)	1.74 (37,997)	0.91
30-34	13.70 (365)	1.93 (1,038)	1.90 (2,633)	3.90 (4,107)	2.05 (8,780)	3.71 (4,858)	0.83 (1,204)	0.00 (190)	2.80 (23,175)	1.47*
35-49	24.10 (83)	0.00 (155)	0.00 (472)	5.39 (927)	4.53 (3,529)	5.55 (4,688)	4.99 (3,406)	4.54 (1,984)	4.92 (15,244)	2.57***
All	3.67 (33,213)	1.64 (27,993)	1.13 (23,004)	1.92 (17,719)	2.62 (22,559)	4.40 (11,137)	3.78 (4,768)	4.11 (2,192)	2.54 (142,585)	
Odds ratio	2.24***	1.00	0.69	1.17	1.59*	2.68***	2.29**	2.50*		

Number of pregnancies in parentheses. Mortality probabilities are not presented for cells where the number of pregnancies is less than 50.

*=p<0.05, **=p<0.01, ***=p<0.001 (tests of the significance of the difference from the reference category).

Table V-4. Probability of maternal death (deaths per 1,000 pregnancies) by the number of previous child deaths and the number of previous pregnancy losses, Matlab, 1982-2002

Factors	Probability	Odds ratio	Number
Prior child deaths			
None (RC)	2.21	1.00	101,686
1	2.98	1.35*	27,176
2 or more	4.04	1.83***	14,086
Prior pregnancy losses			
None (RC)	2.45	1.00	112,185
1	2.51	1.03	22,693
2 or more	3.85	1.57*	8,068
All	2.54	--	142,948

RC = Reference category for the odds ratios.

*=$p<0.05$, ***=$p<0.001$ (tests of the significance of the difference from the reference category).

Table V-5. Probability of maternal death (deaths per 1,000 pregnancies) by socio-economic and other factors, Matlab, 1982-2002

Factors	Probability	Odds ratio	Number
Woman's education			
No schooling (RC)	2.95	1.00	73,785
1-5 years of schooling	2.37	0.80+	43,497
6-10 years of schooling	1.63	0.55**	23,286
11+ years of schooling	1.68	0.57	2,380
Husband's education			
No schooling (RC)	3.08	1.00	69,169
1-5 years of schooling	2.19	0.71**	42,007
6-10 years of schooling	1.85	0.60**	24,870
11+ years of schooling	1.74	0.57+	6,902
Household space			
Low (<170 sq. ft.) (RC)	2.82	1.00	38,707
Low – Medium (170-249 sq. ft.)	2.56	0.91	35,106
Medium (250-349 sq. ft.)	2.86	1.01	33,536
High (350 + sq. ft.)	1.87	0.65**	35,364
Religion			
Muslim (RC)	2.52	1.00	127,426
Non-Muslim	2.71	1.07	15,522
Area			
Comparison (RC)	2.92	1.00	77,495
Treatment	2.09	0.72**	65,453
All	2.54	--	142,948

RC = Reference category for the odds ratios.

+=<0.10, **=p<0.01 (tests of the significance of the difference from the reference category).

Table V-6. Probability of maternal death (deaths per 1,000 pregnancies) by calendar year and area, Matlab, 1982-2002

Time	Comparison Area			Treatment Area			Both areas		
	Proba-bility	Odds ratio	Number	Proba-bility	Odds ratio	Number	Proba-bility	Odds ratio	Number
1982-1987 (RC)	4.25	1.00	24,022	3.35	1.00	19,997	3.84	1.00	44,019
1988-1992	2.21	0.52**	19,921	1.71	0.51**	15,819	1.99	0.52***	35,740
1993-1997	2.81	0.66*	16,349	2.10	0.63*	14,275	2.48	0.65**	30,624
1998-2002	1.98	0.47***	17,203	0.85	0.25***	15,362	1.44	0.38***	32,565
All	2.92	-	77,495	2.09	-	65,453	2.54	-	142,948

RC = Reference category for the odds ratios.

*=p<0.05, **=p<0.01, ***=p<0.001.

Table V-7: Logistic regression estimates of odds ratios of factors associated with maternal mortality, Matlab, 1982- 2002 (n=142,948)

Factors	Model 1		Model 2 (with interactions)	
Maternal age				
<18 years	0.98		0.99	
18-19	1.13		1.13	
20-24 (RC)	1.00		1.00	
25-29	1.41	+	1.41	+
30-34	2.46	***	2.47	***
35-39	3.69	***	3.69	***
40-44	7.35	***	7.35	***
45-49	4.95	*	4.89	*
Interpregnancy interval				
< 6 months	1.28		1.28	
6-14 months	0.98		0.98	
15-26 months	0.99		1.00	
27-50 months (RC)	1.00		1.00	
51-74 months	1.10		1.10	
75+ months	1.96	*	2.00	*
Missing data on interval length	1.19		1.19	
Gravidity				
First pregnancy	3.91	***	4.04	***
2 (RC)	1.00		1.00	
3-4	0.75		0.75	
5-7	0.67		0.67	
8+	0.31	**	0.31	**
Number of prior child deaths				
0 (RC)	1.00		1.00	
1	1.64	**	1.64	**
2+	1.83	**	1.83	**
Number of prior pregnancy losses				
0 (RC)	1.00		1.00	
1	1.28		1.27	
2+	1.91	**	1.90	**
Woman's education				
No schooling (RC)	1.00		1.00	
1-5 years of schooling	0.93		0.93	
6-10 years of schooling	0.72	+	0.72	+
11+ years of schooling	0.70		0.71	
Household space				
Low (RC)	1.00		1.00	
Low-medium	0.88		0.88	
Medium	1.01		1.01	
Medium-high	0.70	*	0.70	*
Religion				
Muslim (RC)	1.00		1.00	
Non-Muslim	1.12		1.12	
Study area				
Comparison (RC)	1.00		1.00	
Treatment	0.70	**	0.77	
Time period				
1982-1987 (RC)	1.00		1.00	
1988-1992	0.53	***	0.54	**
1993-1997	0.62	**	0.64	*
1998-2002	0.34	***	0.42	***
Time period * Study area				
1988-1992 * Treatment	-		0.96	
1993-97 * Treatment	-		0.91	
1998-2002 * Treatment	-		0.53	+
Model constant	-6.25		-6.28	
-2 Log likelihood	4,862.55		4,859.14	

RC = Reference category for the odds ratios.

+=P< 0.10; * = P< 0.05; ** = p<0.01; and *** = p<0.001

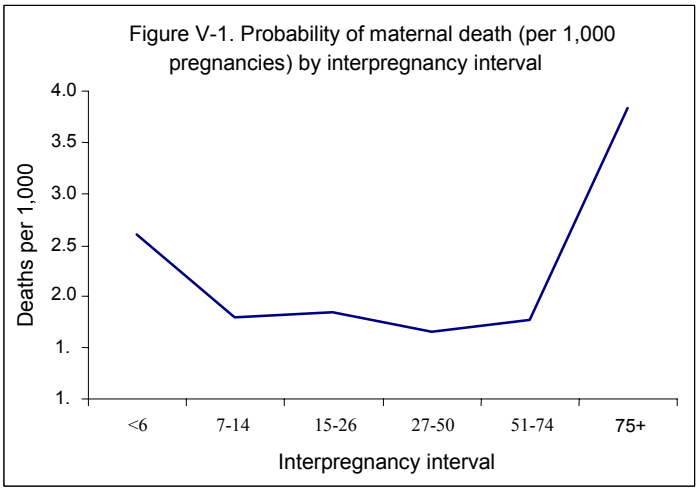


Figure V-1. Probability of maternal death (per 1,000 pregnancies) by interpregnancy interval
Deaths per 1,000
4.0
3.5
3.0
2.5
2.0
1.
1.
<6
7-14
15-26
27-50
51-74
75+
Interpregnancy interval

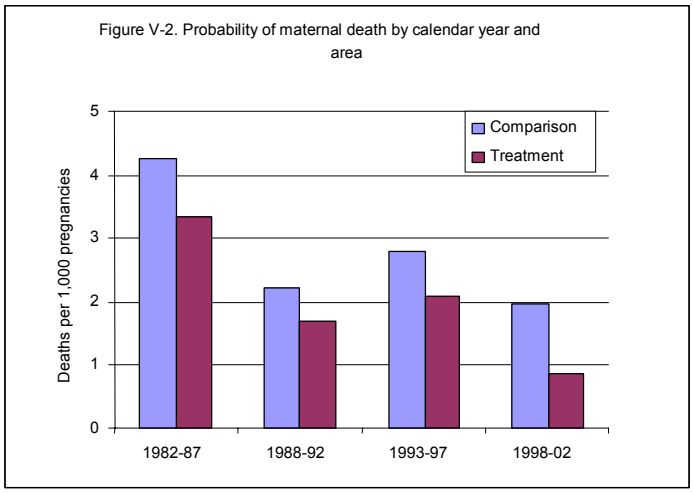


Figure V-2. Probability of maternal death by calendar year and area
Deaths per 1,000 pregnancies
5
4
3
2
1
0
Comparison
Treatment
1982-87
1988-92
1993-97
1998-02

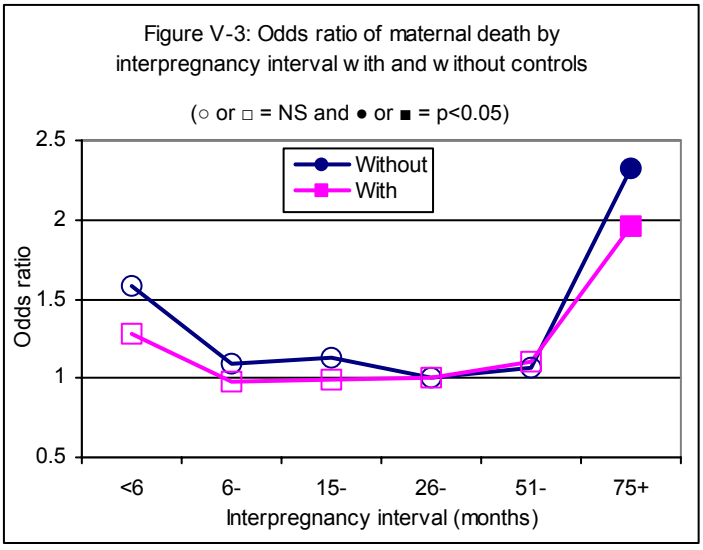


Figure V-3: Odds ratio of maternal death by interpregnancy interval with and without controls
(○ or □ = NS and ● or ■ = p<0.05)
Odds ratio
2.5
2
1.5
1
0.5
Without
With
<6
6-
15-
26-
51-
75+
Interpregnancy interval (months)

VI. INTERPREGNANCY INTERVALS AND MATERNAL MORBIDITY IN MATLAB, BANGLADESH

Introduction

Every year over 54 million women suffer from complications during pregnancy and childbirth. Of those, about 1.5 million die; 99 percent of these deaths occur in the developing countries (World Health Organization, 1993; World Health Organization and United Nations Children's Fund, 1996). In this chapter we assess the extent to which birthspacing affects maternal morbidity and whether programs that attempt to change birthspacing patterns can help reduce such adverse outcomes for women. Such a health rationale has long been one of the reasons for supporting family planning programs in developing countries.

A number of studies (e.g., Hobcraft et al., 1985; Blacker, 1987; Koenig et al., 1988; Zimicki, 1989; Miller et al., 1992) have attempted to estimate the effects of birth intervals on infant and child mortality. Much less is known about the effect of pregnancy spacing on *maternal morbidity*. In an early study that did not control for any possibly confounding influences, Eastman (1944) found no relation between the duration of the interval preceding an index pregnancy and maternal anemia, postpartum hemorrhage, and puerperal fever during that pregnancy. However, that study did find that the likelihood of pre-eclampsia and eclampsia increased steadily with increasing length of the interval between pregnancies. In a recent study, Conde-Agudelo and Belizán (2000) found that, after adjustment for major confounding factors,[30] compared with women conceiving 18 to 23 months after a previous birth, women with interpregnancy intervals of 5 months or less had significantly higher risks of third-trimester bleeding, premature rupture of membranes, anemia, and puerperal endometritis. They also found that women with interpregnancy intervals longer than 59 months had significantly increased risks of pre-eclampsia and eclampsia.

[30] Maternal age, number of previous deliveries, history of miscarriage, stillbirth and early neonatal death, previous caesarean delivery, marital status, education, cigarette smoking, body mass index before pregnancy, trimester during which prenatal care was started, number of prenatal care visits, geographic area, hospital type, and year of delivery.

Eastman's study did not control for confounding factors, and the number of women with short intervals was very small. By contrast, Conde-Agudelo and Belizán (2000) did control for confounding factors and considered a large sample, from Latin America and the Caribbean. Their study is hospital based, but is for a setting where most women deliver in hospital. The data on maternal morbidity for our study are collected at the facility level. We consider pregnant women living in the MCH-FP Area between 1996 and 2002 who came to a community health center for an antenatal checkup during the third trimester of pregnancy. We use these data to investigate whether the durations of interpregnancy intervals (both short and long) affect the likelihood of maternal morbidity for women who visited a health center during their third trimester of pregnancy.

Study Population

The data for this study come from the MCH-FP Area of Matlab. Since 1996, the Reproductive Health Unit of the ICDDR,B has been collecting data on maternal morbidity from women in the MCH-FP Area who visit a health center for an antenatal check-up. All pregnant women in that area are given a "pictoral" card by the community health worker (CHW) when their pregnancies are identified by the CHWs during their monthly household visits for collecting surveillance data (for the DSS and RKS). The woman keeps the card and brings it when visiting the health center for service. The card records information on service uptake, including antenatal check-up, delivery, and postnatal check-up. It also contains behavior change communication messages regarding, for example, pregnancy danger signs, pregnancy planning, and maternal nutrition.

There are four health centers in the MCH-FP area; each covers a population of over 25,000. These centers are equipped to provide basic emergency obstetric care for the catchment area and are posted with a trained nurse-midwife along with a paramedic. These nurse-midwives and paramedics have been trained to provide antenatal care, treat minor complications, conduct normal deliveries, and refer cases with complications to Matlab Hospital.

At the health center, the nurse-midwife examines the women clinically and administers simple laboratory tests. A substantial portion of the health information is

also verified by a female medical officer who visits the center from the Matlab head office every week. Our analyses are based on information on those women who visited health centers during third trimester of the pregnancy. If the woman made more than one visit during the third trimester, we consider the last such visit. Hence, we consider only one observation on each pregnancy.[31]

Data and Definitions of Variables Considered in Our Analyses

Two sources of data are used for the study. Data on maternal age, pregnancy history (gravidity and loss of pregnancy), education of women, household space, and religion were taken from the DSS database. Data on maternal morbidity were taken from the "pictoral" cards mentioned above. In the DSS, the woman's date of birth is collected at her first entry into system, while pregnancy history data are updated regularly through the pregnancy record. For this analysis, maternal age has been calculated at the time of the detection of the pregnancy (usually 6-10 weeks of gestation).[32]

The duration of the interpregnancy interval preceding the index pregnancy is defined as the time elapsed between the date of the woman's preceding pregnancy outcome and the date of the last menstrual period before the index pregnancy. Although conception typically occurs at two weeks (or more) after the last menstrual period, the measure we use is the same as that used in the recent study by Conde-Agudelo and Belizán (2000), to which we compare our results. In calculating the duration of the interpregnancy interval, the date of previous pregnancy outcome was taken from the DSS database using the unique identification number maintained by the system.

Information on women's education, household space, and religion are not regularly updated in the DSS. For all except women who moved to Matlab after 1996, we use information on women's education, household space, and religion collected in a 1996 census. For people who moved to Matlab after the 1996 census, education data were collected at the time they moved into the Matlab area. Women's education is

[31] However, since the data cover seven years, the same women may come for service with more than one pregnancy. We have multiple observations on 2,449 women. We will investigate the effects of this clustering on our standard errors.

[32] Note age is measured at a somewhat different time in this study of maternal morbidity – at the time of the detection of the index pregnancy – than in our study of pregnancy outcomes and infant and child mortality, where it is measured at the time of the outcome

recorded as completed years of schooling, while household space was recorded in square feet. (If the family possesses more than one dwelling, we add the square footage of each of them.)

For maternal morbidity, we consider complications that were noted during the woman's last antenatal visit during the third trimester of pregnancy. The complications considered are high blood pressure (instrument based), anemia (clinical[33]), edema (clinical), proteinuria (laboratory test), bleeding (clinical), and premature rupture of membranes (clinical). Pre-eclampsia is defined as the presence of any two of edema, proteinuria, or high blood pressure. High blood pressure is defined here as a diastolic of 90 mmHg or more.

Results

The DSS identified 21,244 pregnancies in the MCH-FP area during the study period (1996-2002). In 11,122 (52.4%) of these cases, women came to the health center for an antenatal check-up during the third trimester of the pregnancy (Table VI-1). Of the women who did not come to the health center during the third trimester, some came during the first or second trimester of pregnancy (1,243 women), but most never came to a health center at all for an antenatal check-up during that pregnancy (8,879 women).

Of the 11,122 women who visited a health center during the third trimester, for 7,008 of them the visit during the third trimester was their first antenatal visit during that pregnancy; it was the second visit during the pregnancy for 3,021, the third visit for 711, and the fourth visit for 322.

Among the three categories of no visit, first- or second-trimester visit only, and third-trimester visit, mean ages of women are similar, but gravidity and number of pregnancy losses varied slightly, each being lowest for those who had a third-trimester visit (Table VI-1). Women who had an antenatal visit during the third trimester had longer interpregnancy intervals than the women with no visits or only first- or second-trimester visits, but education was much higher for those who had at least one antenatal visit (regardless of trimester) compared to those who had no visits. On the other hand, mean household space was slightly lower for those who had third-trimester visits

compared to the other categories. There is very little difference by religion among the three groups. None of these differences, however, are statistically significant.

Table VI-2 shows maternal morbidity during third trimester of pregnancy by whether it was the woman's first, second, or last antenatal visit during the third trimester. As mentioned earlier, 11,122 pregnant women visited health center during third trimester and of them, 4,054 women had more than one visit during the third trimester. In Table VI-2 we show the incidences of the seven morbidities we consider as measured at three points in time: at the time of the first antenatal visit during the third trimester (for all 11,122 women who had a third-trimester visit), the second visit (for the 4,054 women which had a second visit), and the last visit for (all 11,122 women who had a third-trimester visit some of the "last" visits were first or second visits). We see that, with the exception of anemia, the incidence of each type of morbidity is always lower during the first visit than during the second visit, and that the incidence for the last visit is somewhere in between that for the first and second (which occurs because last visits are largely a mix of first and second visits). Except anemia, morbidity during the second visit is significantly higher than during the first visit. There are no significant differences in morbidity between second and last visit except for proteinuria. The fact that there is a higher incidence of morbidities for women with a second visit during the third trimester suggests that those who have a problem detected during their first visit during the third trimester are more likely to come back for a second visit. In this chapter, we consider morbidities during the *last* visit during the third trimester, since that is when women are most likely to have the morbidities that we analyze.

The incidences of edema and high blood pressure during the last antenatal visit during the third trimester shown in Table VI-2 are generally similar to those Akhter et al. (1996) reported for Bangladesh, but that study found a higher level of bleeding than we do, perhaps because they studied an earlier period of time (1992-94) than we do (1996-2002). Levels of morbidity reported by Conde-Agudelo and Belizan (2000) are generally higher than those we find during the last antenatal visit during the third trimester: 1.6 times higher for pre-eclampsia, 2.4 times higher for bleeding, and 4.5 times for premature

[33] Clinical means physical examination of the body.

rupture of membranes. We do not know the reasons for why the levels appear to be so much lower in Bangladesh.

Bivariate Results

Table VI-3 shows how the incidences of our various measures of maternal morbidity during the last antenatal visit during the third trimester of pregnancy vary according to women's sociodemographic characteristics. Pre-eclampsia, proteinuria, high blood pressure, bleeding, premature rupture of membranes, and edema all tend to be higher for women with short interpregnancy intervals (under 6 months) and long intervals (over 75 months) compared to intervals of 27-50 months in duration. In the two extreme interval categories (under 6 and over 75 months), pre-eclampsia, high blood pressure, and premature rupture of membranes are significantly higher compared to the 27-50-months interval category, while the likelihoods of proteinuria, anemia, and edema are all significantly higher for the longest interval category. For the shortest and longest interpregnancy interval categories, respectively, compared to an interval category of 27-50 months, pre-eclampsia was 2.4 and 2.2 times more likely, proteinuria was 1.1 and 1.4 times more likely, high blood pressure was 2.0 and 2.5 times more likely, bleeding was 1.8 and 1.2 times more likely, premature rupture of membranes was 2.5 and 1.9 times more likely, anemia was 1.0 and 1.2 times more likely, and edema was 1.2 and 1.4 times more likely. All of the morbidities we consider except for anemia are more likely for first pregnancies compared to higher-order pregnancies with a preceding interval of 27-50 months. Anemia is significantly lower for first pregnancies compared to higher-order pregnancies with an interval length of 27-50 months.

Pre-eclampsia and proteinuria have an inverted-U shaped relationship with women's age, whereas high blood pressure, bleeding, and edema have a J-shaped relationship; premature rupture of membranes has a U-shaped relationship; and anemia has a weak positive relationship (Table VI-3). The risks of morbidities are usually higher for the lowest gravidity, except for bleeding and anemia, which generally increase monotonically with gravidity. All morbidities except premature rupture of membranes and edema are higher, and often substantially so, for those who had two or more previous pregnancy losses than those with none or one.

In our data, more highly educated women have lower levels of bleeding and anemia (Table VI-3), perhaps because they have a better diet and are more careful in performing their daily activities during pregnancy than women with less education. However, more highly educated women have higher levels of pre-eclampsia, proteinuria, high blood pressure, premature rupture of membranes, and edema than uneducated women. This may occur because educated women are more likely to visit the health center when they experience such symptoms. If this is the case, the differentials we see may be due to the selectivity of the sample rather than to true differences in the incidence of the morbidity, and this makes the lower levels of bleeding and anemia for more educated women all the more noteworthy. No systematic morbidity pattern was observed by household space except for anemia, which occurs more often for women with little household space. (This may be due to poorer women having a less iron-rich diet.) Muslims are less likely than non-Muslims to have pre-eclampsia, high blood pressure, bleeding, and edema, but non-Muslims had slightly lower incidences of proteinuria, premature rupture of membranes, and anemia than Muslims.

Multivariate Analyses

Table VI-4 presents odds ratios from our logistic regressions. After controlling for all variables in the regression model, pre-eclampsia and high blood pressure are significantly more likely for women with preceding interpregnancy intervals of less than 6 months and over 75 months compared to those with intervals of 27-50 months, while for edema, the odds ratio is significantly higher for intervals over 50 months. We see similar patterns for proteinuria and premature rupture of membranes, but the interval effects are not statistically significant. The other morbidities we consider (bleeding and anemia) do not vary significantly by the duration of the interpregnancy interval in our multivariate analyses. In general, the relationships between interpregnancy intervals and morbidity that we see in our multivariate analyses are very similar to those we saw earlier in our bivariate analyses. (See Figures VI-1a-g.)

Except for premature rupture of membranes, the likelihoods of all other morbidities are usually lower for the younger age categories, but all morbidities are more likely in the older age categories compared to ages 20-24. Except for edema, morbidity

is higher for those who had two or more pregnancy losses than those with none, though the differences aren't always statistically significant.

Except for bleeding and anemia, educated women usually had higher levels of morbidity than less educated women, and the differences are usually significant. No consistent morbidity pattern by household space is observed. Non-Muslims have significantly higher rates of pre-eclampsia and high blood pressure than Muslims. The same pattern is seen for bleeding and edema, but the differences by religion are not statistically significant. For the rest of the morbidities, non-Muslims usually have a lower risk, but the differences are not statistically significant.

Discussion

The data for the study were collected at the facility level and refer to the 52 percent of pregnant women in the MCH-FP area who visited the health center for antenatal care during their third trimester of pregnancy. Although it is likely that those women who visited the health center could have experienced more health problems than those who did not, it is also possible that those who visited the health center were more health conscious than those who did not.

After controlling for the other variables in our multivariate analyses, we find that women with short interpregnancy intervals (<6 months) had a higher risk of pre-eclampsia ($p<.01$), proteinuria (NS), high blood pressure ($p<.10$), premature rupture of membranes (NS, though intervals of 6-14 months are associated with a significantly higher incidence), anemia (NS), and edema (NS) compared to those with an interval of 27-50 months. Women with very long interpregnancy intervals (75+ months) had a higher risk of pre-eclampsia ($p<.05$), proteinuria (NS), high blood pressure ($p<.10$), premature rupture of membranes (NS), and edema ($p<.01$) compared to women with intervals of 27-50 months. Pre-eclampsia and high blood pressure are significantly higher for the shortest (<6 months) and longest (75+ months) intervals compared to those of 27-50 months, while edema is significantly higher for the longest intervals.

Our study has three morbidities (bleeding, premature rupture of membranes, and anemia) in common with those considered by Conde-Agudelo and Belizán (2000) and two morbidities (anemia and pre-eclampsia) in common with those studied by Eastman

(1944). Premature rupture of membranes was more likely for short interpregnancy intervals both in Conde-Agudelo and Belizán's study and our study, while anemia was more likely for short intervals in Conde-Agudelo and Belizán's study but not in ours. All the three studies find a higher likelihood of pre-eclampsia for the longest interpregnancy intervals, but our study also finds higher pre-eclampsia for the shortest interval duration. None of these studies found any relation between interpregnancy intervals and anemia, though we find that the risk of anemia is lowest for women in their first pregnancy.

The implications of these findings are similar to those discussed in the previous chapter.

Table VI-1. Women's socio-demographic characteristics (mean) by timing of last antenatal visit (if any), MCH-FP area, 1996-2002

Characteristics	Antenatal visit		
	No visit	First/second-trimester visit	Third-trimester visit
Interpregnancy interval* (months)	42.6	42.6	43.9
Women's age (years)	26.4	26.4	26.3
Gravidity	2.9	2.8	2.7
No. of previous pregnancy losses	0.4	0.3	0.3
Women's education (years)	2.8	4.5	4.3
Household space (sq. feet)	305	300	298
Religion (% Muslim)	87	86	86
n	8,879	1,243	11,122

*First pregnancy excluded.

Table VI-2. Incidence of maternal morbidity (per 100 pregnancies) during first, second, and last visits for antenatal care during the third trimester of pregnancy, MCH-FP area, 1996-2002

Morbidity	**Third trimester**		
	First visit	**Second visit**	**Last visit**
Pre-eclampsia	1.6 ***	3.1	2.7
Proteinuria	3.8 ***	5.7	4.4 +++
High blood pressure	1.8 ***	3.5	3.3
Bleeding	0.3 ***	0.7	0.5
Premature rupture of membranes	0.7 ***	1.6	1.5
Anemia	18.3	17.6	18.6
Edema	18.2 ***	22.9	21.9

*** Difference between first and second visit is statistically significant at p<0001.
+++ Difference between second and last visit is statistically significant at p<0.001.
*Many last visits were first or second visits.

Table VI-3. Maternal morbidity per 1,000 pregnancies according to women's socio-demographic characteristics, Matlab MCH-FP area, 1996-2002

Characteristics	Pre-eclampsia	Protein-uria	High blood pressure	Bleeding	Premature rupture of membranes	Anemia	Edema
Woman's age (in years)							
<20	26.2	40.4	31.0	4.7**	20.8	122.2	217.7
20-24 (RC)	29.8	47.8	31.9	4.7	15.8	136.2	214.6
25-29	26.5	42.6	29.7	2.5	14.3	186.9***	206.3
30-34	25.9	42.8	39.3	5.5	11.2	252.0***	223.9
35+	21.1	42.9	36.7	11.1**	13.2	306.9***	263.2***
Gravidity							
1	37.3***	54.8***	40.1***	4.5	20.3**	111.4***	237.4***
2 (RC)	24.0	36.4	26.5	2.4	12.5	169.3	205.7
3-4	19.4	40.4	30.0	5.9**	13.6	206.3***	207.3
5-6	27.3	45.4	36.9*	6.9*	12.0	329.4***	235.9**
7+	21.3	30.9	37.2	9.8**	3.1	405.9***	205.5
No. prev. pregnancy losses							
0 (RC)	25.9	44.3	31.1	3.4**	14.0	174.1	217.2
1	27.2	40.8	37.3	10.4	19.8*	215.0***	229.1
2+	44.8*	49.5	56.3*	11.5	15.2	314.0***	215.2
Woman's education (in completed years)							
0 (RC)	22.1	37.8	25.3	6.9**	12.2	239.6	214.5
1-5	23.4	39.3	32.3	3.5	12.5	186.8***	202.2
6+	35.1***	52.8***	42.0 ***	3.7*	19.7**	124.3***	234.3**
Household space							
Low (RC)	26.1	35.5	33.2	3.8	15.0	205.4	234.9
Low-medium	25.2	54.1***	30.2	5.5	9.5*	195.4	199.6***
Medium	25.9	45.7*	37.3	6.2	15.7	170.8***	209.4**
High	30.3	43.8	31.1	3.9	18.7	172.7***	226.3
Religion							
Muslim (RC)	25.5	44.7	31.5	4.6	15.7	188.2	217.3
`Non-Muslim	35.0**	39.9	41.9**	6.2	10.3	195.3	228.7
Interpregnancy interval (months)							
<6	42.2***	40.7	45.2***	7.7	19.2**	212.2	219.0
6-14	19.3	42.4	15.9	7.8	26.5***	208.6	185.5
15-26	19.9	35.1	30.4	3.6	12.4	236.1	177.7
27-50 (RC)	17.6	35.7	22.6	4.2	7.8	213.2	188.6
51-74	19.4	41.4	26.3	6.3	9.2	229.9	238.5***
75+	38.3***	50.2**	57.6***	4.9	14.8*	248.8**	266.7***
First pregnancy	37.3***	54.8*	40.1***	4.5	20.3***	111.4***	237.4***

Note: RC= reference category

Comparison is made with reference category for tests of statistical significance

*p<0.10, **p<0.05, ***p<0.01

Table VI-4. Logistic regression estimates of odds ratios of factors associated with maternal morbidity, MCH-FP area, 1996-2002

Covariates	Pre-eclampsia	Protein-uria	High blood pressure	Bleeding	Premature rupture of membranes	Anemia	Edema
Interpregnancy interval (in months)							
<6	2.19**	1.20	1.66*	0.95	1.94	1.03	1.16
6-14	1.05	1.23	0.56	1.24	2.86*	0.99	0.93
15-26	1.14	0.89	1.25	0.44	1.44	1.09	0.94
27-50 (RC)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
51-74	1.04	1.15	1.09	1.30	1.24	1.06	1.27***
75+	2.44***	1.24	2.44***	0.86	1.78	0.99	1.44***
Woman's age (in years)							
<20	0.71*	0.67**	0.79	0.97	1.07	1.06	0.91
20-24 (RC)	1.00	1.00	1.00	1.00	1.00	1.12	1.00
25-29	1.43**	1.14	1.29	0.43	1.05	1.00	1.10
30-34	1.45	1.05	1.75**	0.71	0.80	1.23*	1.30***
35+	1.27	1.31	1.57	1.55	1.34	1.35**	1.51***
Gravidity							
1	2.17***	1.86***	2.07***	1.76	2.47**	0.67***	1.40***
2 (RC)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3-4	0.66*	1.07	0.88	1.82	1.08	1.03	0.87*
5-6	0.81	1.77	0.91	1.37	0.99	1.78***	0.90
7+	0.37*	0.43	0.86	1.24	0.21	2.41***	0.66**
No. prev. pregnancy losses							
0 (RC)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	0.86	0.98	0.75	0.34***	0.77	1.07	0.87*
2+	1.93*	1.34	1.82**	1.22	1.36	1.13	0.96
Woman's education (in completed years)							
0 (RC)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1-5	1.08	1.06	1.40**	0.48*	0.89	0.82***	0.93
6+	1.43*	1.28*	1.87***	0.60	1.23	0.61***	1.10
Household space							
Low (RC)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low-medium	0.98	1.51***	0.93	1.67	0.73	0.93	0.81**
Medium	0.89	1.15	1.08	2.27*	1.11	0.90	0.85**
High	1.02	1.03	0.79	1.54	1.15	1.00	0.92
Religion							
Muslim (RC)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Non-Muslim	1.48**	0.92	1.85***	1.46	0.69	0.92	1.08
-2 Log Likelihood	2487.4	3313.4	2827.6	548.9	1484.3	8539.7	10408.8
Model constant§	-4.12	-3.64	-4.08	-4.99	-4.64	-1.42	-1.30

Note: RC=reference category

*p<0.10, **p<0.05, ***p<0.01

§ This is the constant for the logistic regression

Figure VI-1a: Estimated odds ratio of having pre-eclampsia by interpregnancy interval, with and without controls
(Hollow symbols indicate odds ratios that aren't signficantly different from 1.0.)

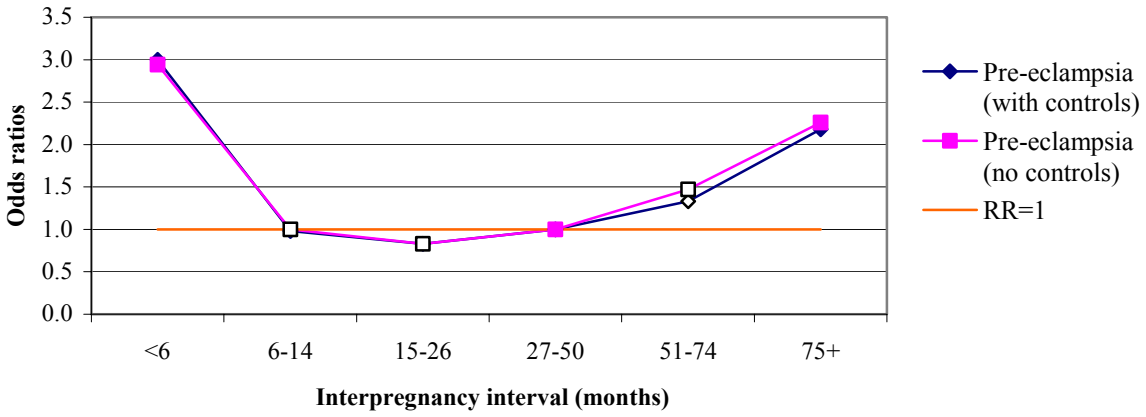


Figure VI-1b: Estimated odds ratio of having proteinuria by interpregnancy interval, with and without controls
(Hollow symbols indicate odds ratios that aren't signficantly different from 1.0.)

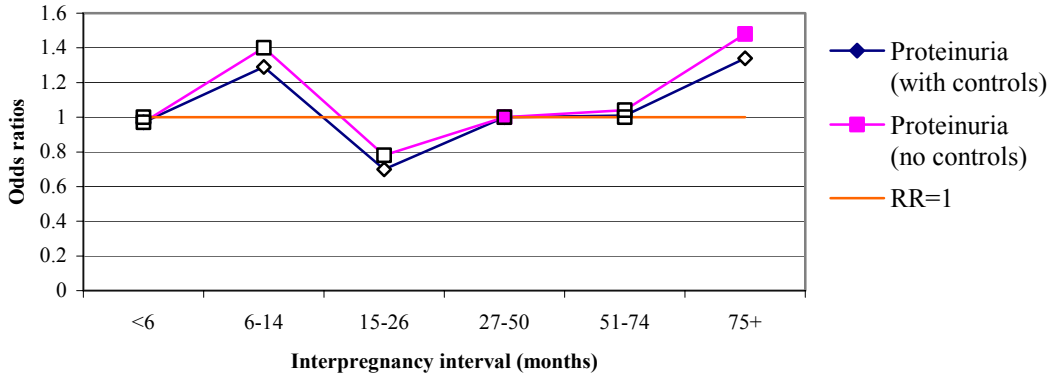


Figure VI-1c: Estimated odds ratio of having high blood pressure by interpregnancy interval, with and without controls
(Hollow symbols indicate odds ratios that aren't signficantly different from 1.0.)

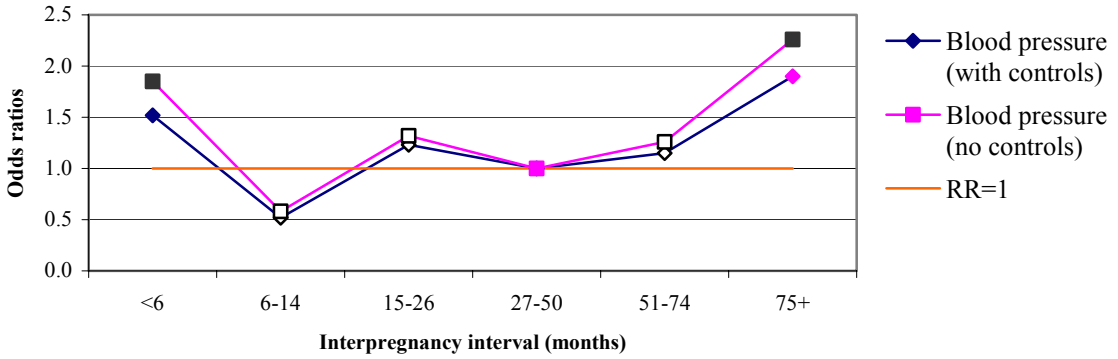


Figure VI-1d: Estimated odds ratio of having bleeding by interpreganancy interval, with and without controls
(Hollow symbols indicate odds ratios that aren't signficantly different from 1.0.)

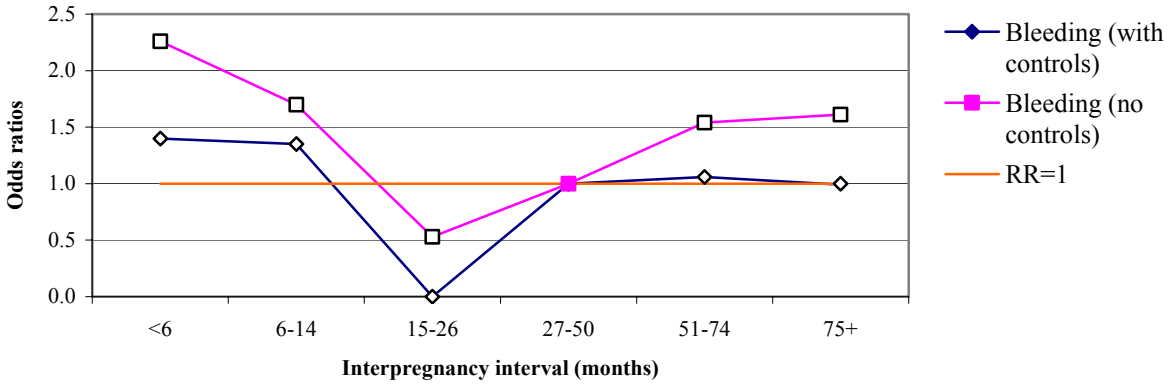


Figure VI-1e: Estimated odds ratio of having premature rupture of membranes by interpregnancy interval, with and without controls
(Hollow symbols indicate odds ratios that aren't signficantly different from 1.0.)

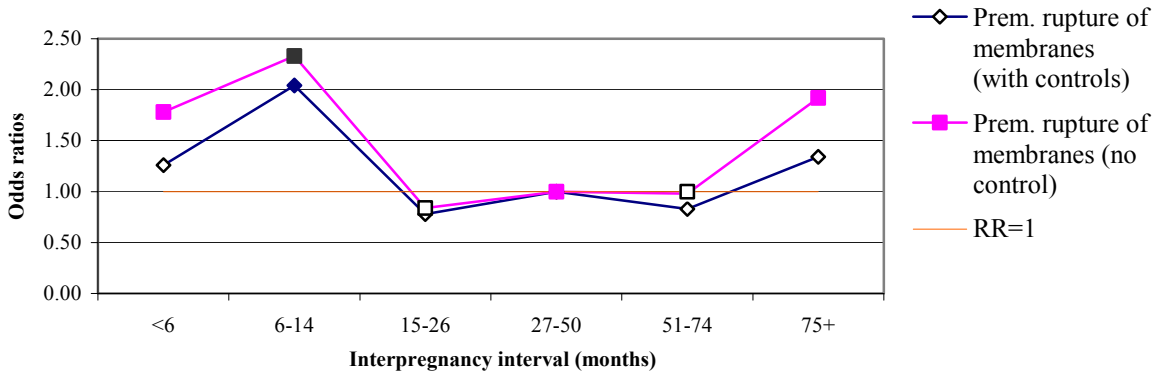


Figure VI-1f: Estimated odds ratio of having anemia by interpregnancy interval, with and without controls
(Hollow symbols indicate odds ratios that aren't signficantly different from 1.0.)

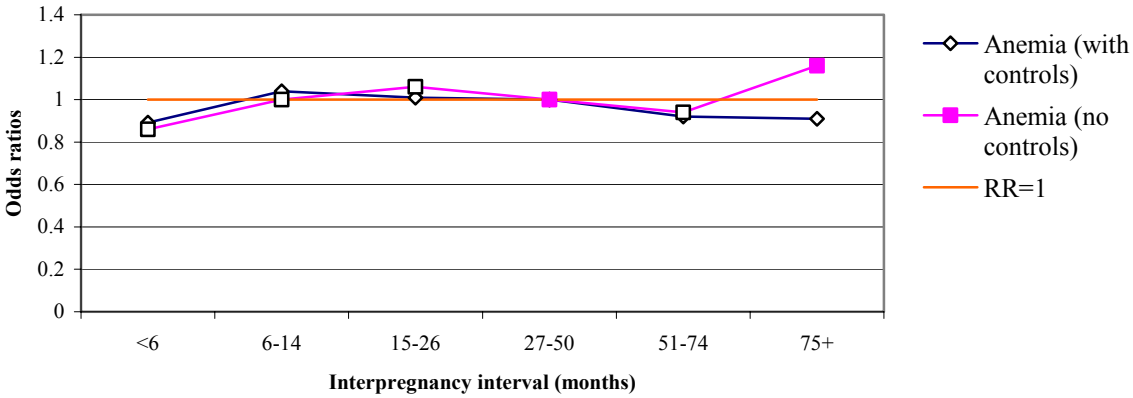
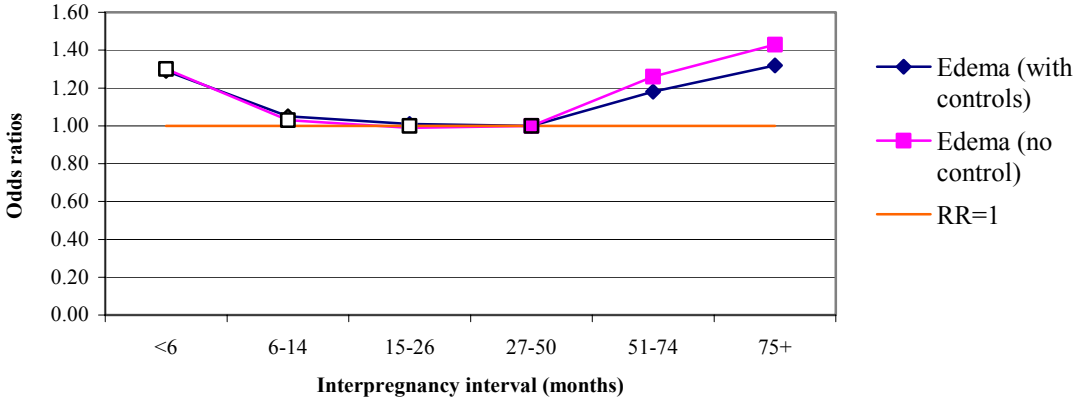


Figure VI-1g: Estimated odds ratio of having edema by interpregnancy interval, with and without controls

(Hollow symbols indicate odds ratios that aren't signficantly different from 1.0.)



VII. CHARACTERISTICS OF WOMEN WHO HAVE VERY SHORT OR VERY LONG INTERVALS

In this section we describe the characteristics of women who have different lengths of intervals, so that we can identify the types of women most likely to have very short intervals as well as those who have very long intervals. We focus on the lengths of *inter-outcome* intervals, though in one case we also present interbirth intervals. With that exception, the findings are very similar for these two measures of intervals.

Pregnancies following short inter-outcome intervals (<36 months) are less likely to be to women who live in the Treatment Area of Matlab (Fig. VII-1). Only 35.2 percent of the pregnancies that occurred less than 36 months after the previous pregnancy outcome were to women in the MCH-FP Area as opposed to 53.7 percent of those for intervals longer than 36 months ($p<.001$). This suggests that women in the Treatment Area are better able to use contraception (more often and more effectively) to control the spacing of their pregnancies.

Women with short intervals are more likely to be of high birth parity than those with longer intervals (Fig. VII-2). Of pregnancies preceded by an inter-outcome interval of less than 36 months, 7.7 percent are of 8^{th} birth order or higher, whereas only 4.6 percent of pregnancies that occur after an interval longer than 36 months are 8^{th} birth order or higher ($p<.001$). Short intervals enable women to reach high parity (more quickly). High-parity women also may be more fecund or less likely to use contraception (effectively) than others.

Women with long inter-outcome intervals (84 months or more) are more likely to be older at the time of the second outcome of the pair of outcomes that define the interval (Fig. VII-3). Pregnancies following inter-outcome intervals of 84 months or more are to women who are on average 34.1 years old, compared with an average age of 28.1 for women with inter-outcome intervals of less than 84 months ($p<.001$). Part of this difference is due to the fact that, for the same age at the outcome at the beginning of an interval, a longer interval means that women are older at the time of the outcome at the end of the interval.

As shown in Figure VII-4, no education among the mothers is most common among pregnancies following inter-outcome intervals of 24-35 months. Specifically, 58.2 percent of the women with the 24-35-month inter-outcome interval have no education. For each of the inter-outcome interval categories, the percentage of women who are Muslim is between 88 percent and 92 percent.

The mean inter-outcome interval has increased in duration since the 1980s, as shown in Figure VII-5. Specifically, in the time period between 1982 and 1986, the mean duration of inter-outcome interval was 24.6 months. In contrast, during the most recent time period, 2000-2002, the mean duration of inter-outcome interval was 46.8 months.

We use two figures, Figs. VII-6 and VII-7, to show the effect of the type of outcome of the pregnancy that immediately precedes the index pregnancy. In Fig. VII-6, we show for each duration of inter-*outcome* interval the distribution of the types of outcomes of the pregnancies that *began* the interval. In particular we show the percentages of those preceding outcomes that were stillbirths, miscarriages, and induced abortions. As shown in Fig. VII-6, we observe that over half (57.3 percent) of the inter-outcome intervals that were less than 15 months in length began with a non-live birth. Specifically, 8.3 percent of women with very short inter-outcome intervals had the preceding pregnancy end with an induced abortion, 34.8 percent had the preceding pregnancy end in miscarriage, and 14.5 percent had the preceding pregnancy end in a stillbirth. One possible explanation for this for miscarriages and stillbirths, which presumably are unexpected events, is that is the women want another child soon and become pregnant again as soon as possible to "replace" the pregnancy they have just lost. This is analogous to the replacement that follows a child death. An additional explanation, which applies to all three types of non-live births, is that the women with previous non-live births are able to become pregnant again sooner than are those with live births because they were not breastfeeding (which is also a reason that intervals tend to be shorter following the births of children who die in infancy).

We get very different results in Figure VII-7, where we consider inter*birth* intervals and show the proportion of those that *included* an intervening non-live birth. This figure shows that the longer the interbirth interval, the more likely it was that there was a non-live birth between the two births. Nearly 21 percent of the very long interbirth

intervals (84 months or more) had at least one intervening non-live birth; of interbirth intervals of 84 months or longer, 6.9 percent had the most recent preceding pregnancy end in abortion, 8.6 percent had the most recent preceding pregnancy end in a miscarriage, and 5.2 percent had the most recent preceding pregnancy end in stillbirth. In contrast, 3.1 percent of interbirth with intervals less than 36 months had an intervening non-live birth in between the two births that define the interbirth interval ($p<.001$). In this case, the intervening non-live birth is a reason why the interbirth interval is long.

One reason why interbirth intervals are long for women with an intervening non-live birth despite the fact that inter-outcome intervals that begin with a non-live birth tend to be short is that some women tend to have repeated non-live births. For example, among index pregnancies in which the preceding pregnancy ended with an induced abortion (n=2,126), 28.1 percent of those index pregnancies resulted in a non-live birth (18.8 percent of the total had another abortion, 6.0 percent had a miscarriage for the second outcome, and 3.3 percent had a stillbirth for the second outcome). In contrast, among index pregnancies in which the preceding pregnancy ended in a live birth (n=75,523), only 11.9 percent of the index pregnancies ended in a non-live birth (4.1 percent of the total were aborted, 5.4 percent miscarried, and 2.4 percent were stillborn). The difference between these two percentages, 28.1 percent and 11.9 percent, is significantly different at $p<.001$.

Figure VII-1. Percentage of Women in the MCH-FP Area by Duration of Inter-Outcome Interval
(A Chi-square test of the distribution of inter-outcome intervals by MCH-FP vs. Comparison Area has a p<.001.)

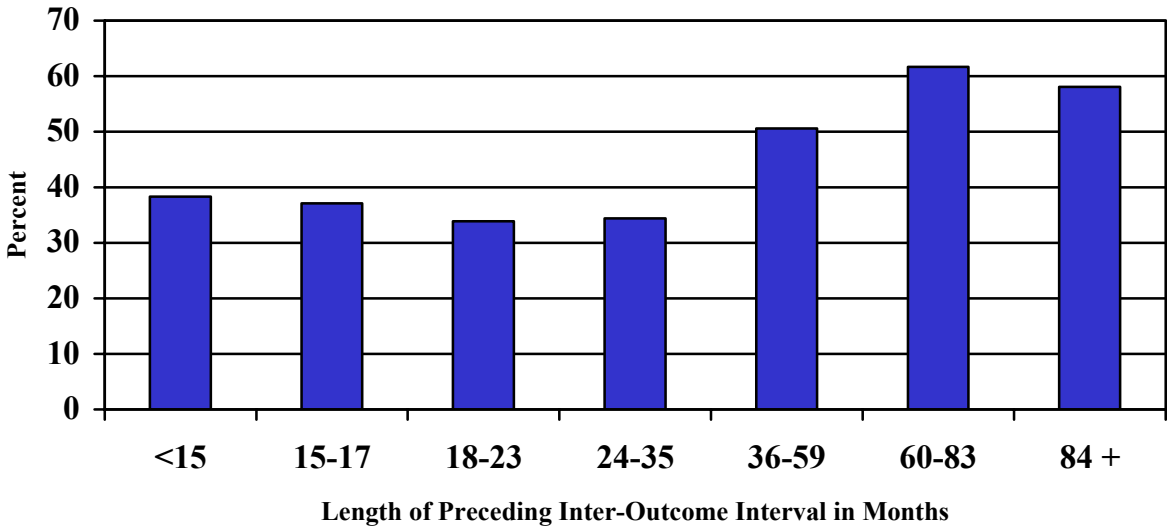


Figure VII-2. Percentage of Pregnancies of Parity 8+ by Duration of Preceding Inter-Outcome Interval
(A Chi-square test of the distribution of inter-outcome intervals by parity>=8 vs. parity <8 has a p<.001.)

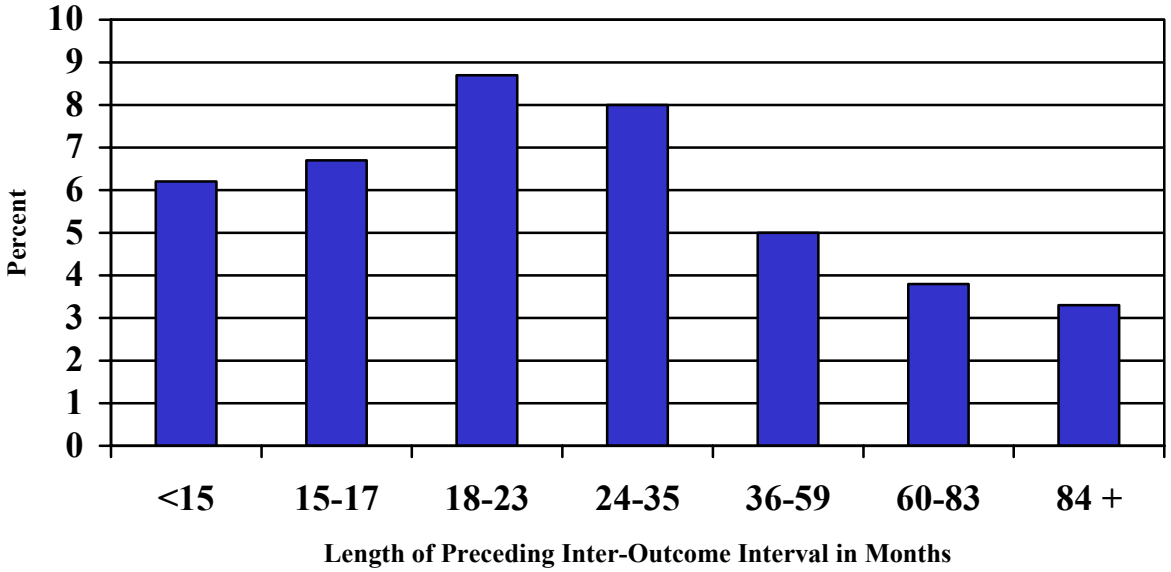


Figure VII-3. Mean Age of Women by Duration of Inter-Outcome Interval
(A Chi-square test of the distribution of maternal age by inter-outcome intervals has a p<.001.)

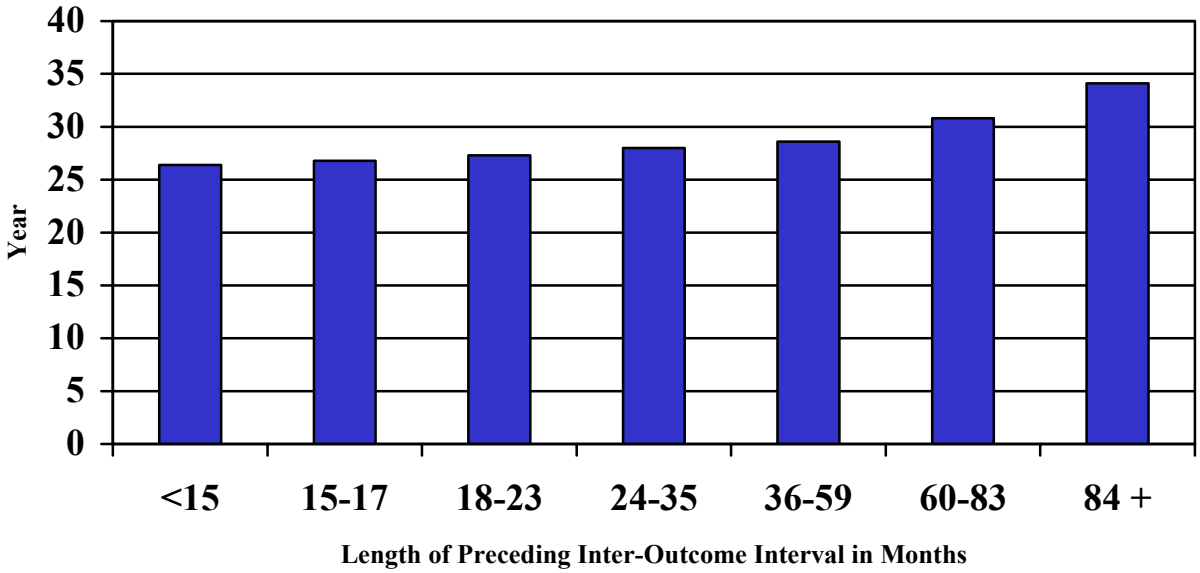


Figure VII-4. Percentage Distribution of Mother's with No Education by Duration of Inter-Outcome Interval
(A Chi-square test of the distribution of inter-outcome intervals by no education vs. any education has a p<.001.)

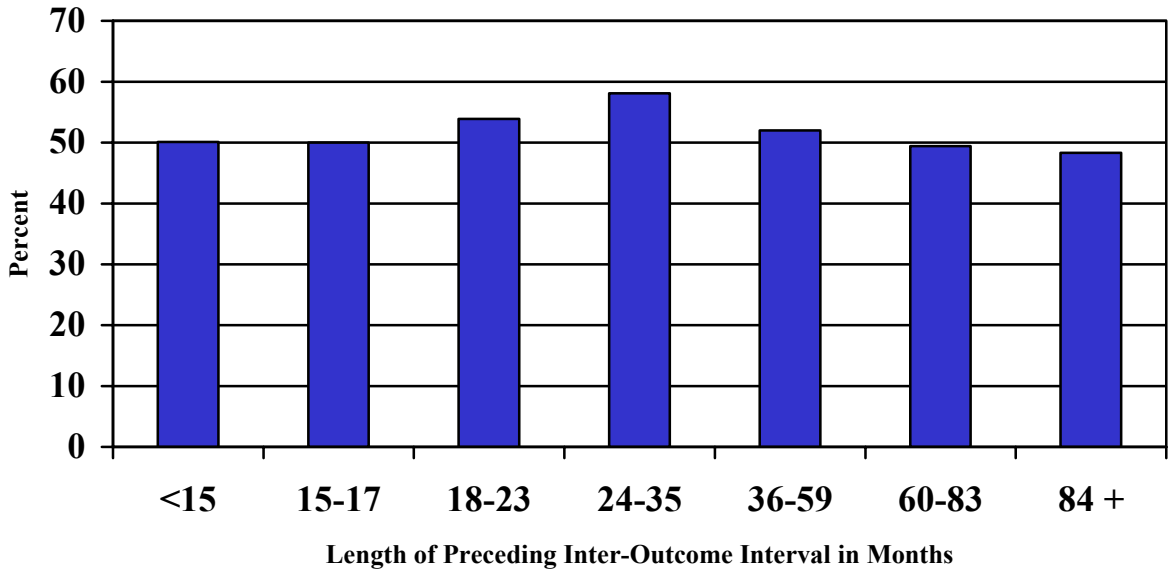


Figure VII-5. Mean Duration of Inter-Outcome Interval by Time Period
(The difference between the mean inter-outcome interval for each time period and its adjacent time period is different from 0 at a significance level of p<.001, except for between 1997-1999 and 2000-2002 where p<.01.)

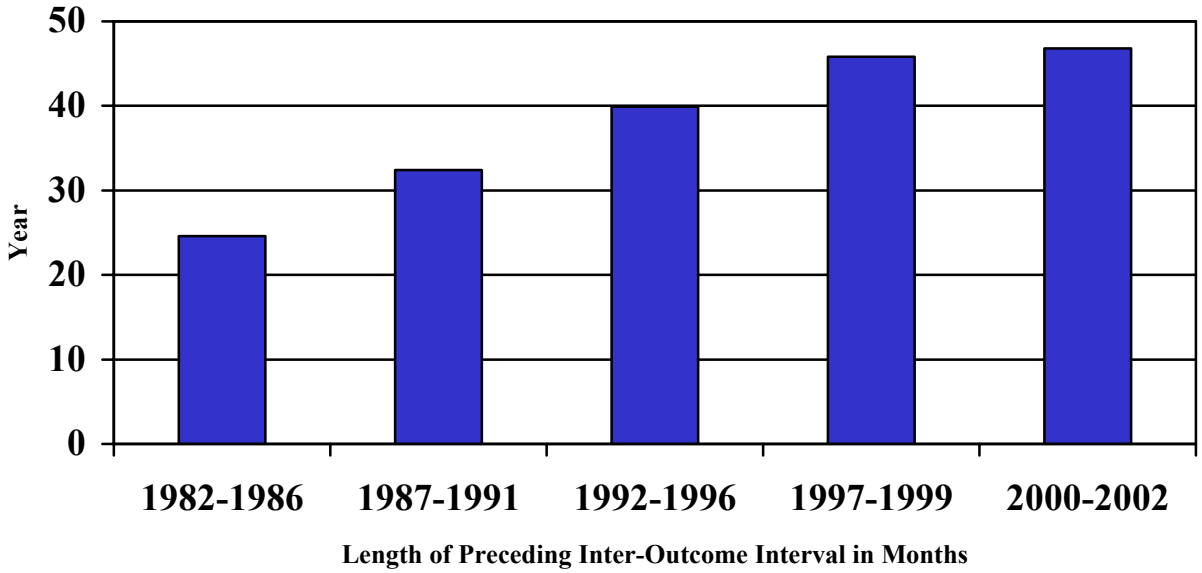


Figure VII-6. Percentage Distribution of Type of Preceding Pregnancy Outcome by Duration of Inter-Outcome Interval.
(A Chi-square test of the distributions of previous pregnancy outcome by inter-outcome intervals has a p<.001.)

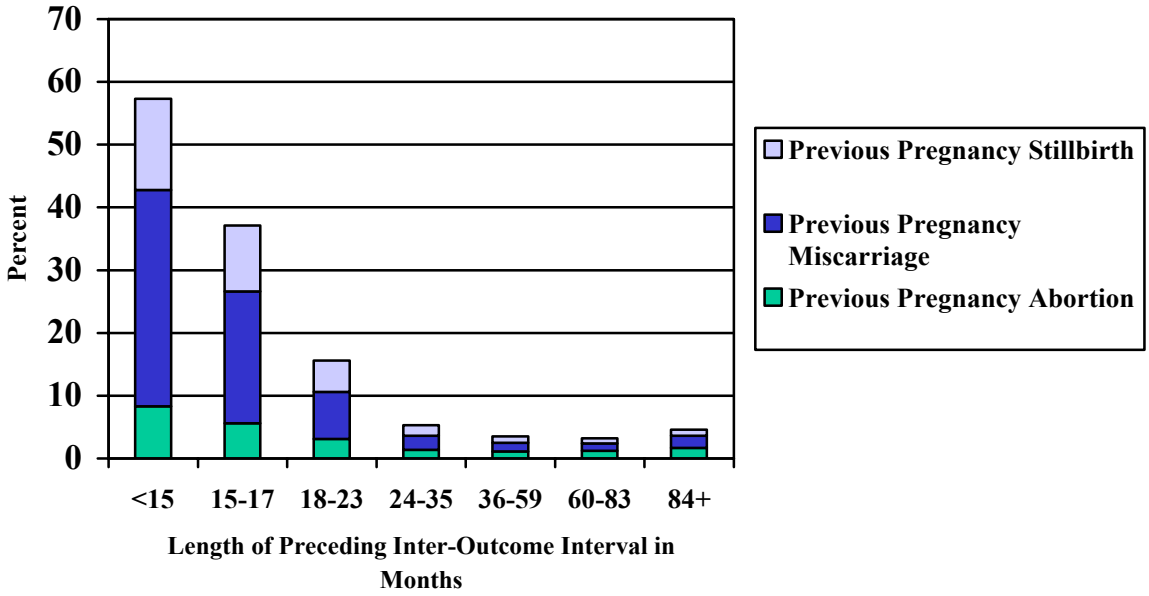
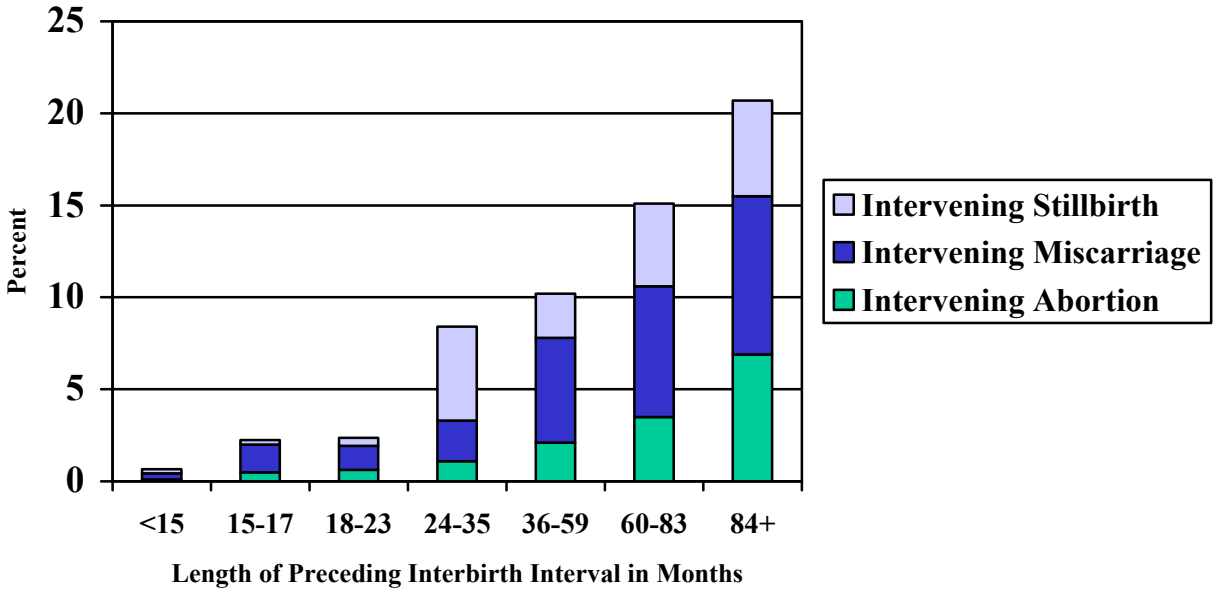


Figure VII-7. Percentage of Intervening Non-Live Births by Duration of Interbirth Interval

(A Chi-square test of the distribution of type of preceding pregnancy outcome by inter-birth intervals has a $p<.001$.)



VIII. CONCLUSION

We conclude by answering the questions posed at the beginning of this report and then discussing some of their implications.

1) To what extent does the length of the preceding birth interval affect the risks of infant and child mortality?
2) Are the interval effects U-shaped? I.e., are both too-short and too-long intervals pernicious? And exactly what durations define too-short and too-long?

We have seen that the risks of infant and child mortality vary significantly with the durations of interbirth intervals when no other variables are controlled. Interbirth intervals of less than 24 months in duration are associated with significantly higher risks of early neonatal mortality, compared with intervals of 3-5 years in duration. Interbirth intervals of less that 36 months are associated with significantly higher risks of late neonatal mortality, post-neonatal mortality, and child mortality compared to intervals of 3-5 years in duration. For early and late neonatal mortality and post-neonatal mortality, for intervals of less than 3 years in duration, mortality risk is higher the shorter the interval; for all three subperiods, the risk is highest for the shortest interbirth interval (less than 15 months). For childhood mortality, interbirth intervals of 18-23 months duration are associated with the highest mortality.

For early neonatal mortality, interbirth intervals of 3-5 years duration have the lowest risk of mortality (though mortality rates are also relatively low and not significantly different for intervals that are 24-35 months and 60-83 months in length). For late neonatal mortality, post-neonatal, and childhood mortality, the mortality risk is lowest for interbirth intervals that are 5-7 years long.

For all four subperiods, mortality risks are somewhat higher for the longest interbirth intervals that we consider – 7 or more years – than for those that are 5-7 years long.

3) To what extent is the "effect" of longer interbirth intervals due to there being a non-live birth between the two births that define the interval? How do the effects of inter*birth* intervals compare to those of inter-*outcome* intervals (the interval back to the last pregnancy outcome, regardless of whether it was a live birth)?

It is true that very long interbirth intervals are more likely to contain an intervening non-live birth than shorter interbirth intervals. Twenty-one percent of interbirth intervals of a duration of seven or more years included at least one intervening non-live birth, whereas 3.1 percent of interbirth intervals less than three years duration included a non-live birth. The effects of very long intervals are somewhat smaller when we consider inter-outcome rather than interbirth intervals, and the pernicious effects of the longest interval on early neonatal mortality is no longer statistically significant.

In general, the effect of inter-outcome intervals are smaller than the effect of interbirth intervals. One reason is that short inter-outcome intervals that began with a non-live birth have a smaller effect on mortality than those that began with a live birth.

4) To what extent is the effect of a short inter-outcome interval on infant and child mortality due to short gestation of the index pregnancy? What are the separate effects of the interpregnancy interval (the interval between the preceding pregnancy outcome and the conception of the index pregnancy) and of the duration of gestation of the index pregnancy?

Short gestation of pregnancy (prematurity) does indeed increase the risk that a baby will die in the early neonatal, late neonatal, and post-neonatal periods, though it does not have a significant effect on childhood mortality. The effects are greater the more premature the birth and the earlier the subperiod that we consider. (I.e., the effects are greatest [RR=8.9] for early neonatal mortality for babies born after a gestation of less than 30 weeks.) Controlling for the duration of the pregnancy reduces the effects of short inter-outcome intervals to a modest degree and, in a few cases, effects that were statistically significant when gestation duration was not controlled are not significant when it is controlled.

5) To what extent are the apparent effects of intervals on infant and child mortality due to factors such as breastfeeding and immunizations that are correlated with pregnancy spacing?

Although the duration of breastfeeding has strong effect of survival between the second and eighteenth months of life, controlling for breastfeeding barely changes the estimates of the effects of inter-outcome intervals on mortality during these subperiods.

Having a diphtheria or measles vaccination prior to the 12-18-months-of-life and 1.5-5-years-of-life subperiods does not affect mortality during those periods. Furthermore, the likelihoods of having these immunizations are not correlated with pregnancy spacing. For both of these reasons, controlling for the child's immunizations has no effect of our estimates of the effects on inter-outcome intervals on mortality.

6) At what ages of child are the interval effects greatest? In particular, do the effects of the length of the preceding interval differ across subperiods of infancy and childhood?

When all of the explanatory variables that we consider are controlled, the largest relative risk is on early neonatal mortality for inter-outcome intervals of less than 15 months that began with a live birth (RR=3.03). The shortest inter-outcome interval is also the most pernicious of all interval lengths considered for late neonatal and post-neonatal mortality, though these are succeedingly smaller (RR=2.33 and 1.80 respectively) than the risk associated with such short intervals for early neonatal mortality. The risk of childhood mortality is greatest for inter-outcome intervals of 18-23 months (RR=1.29, compared to intervals of 3-5 years), though intervals of 24-35 months are also more pernicious (RR=1.21) than shorter or longer intervals.

7) Does the duration of the *subsequent* interval affect the likelihood of survival of the index child when appropriate attention is given to the reverse causality that can arise because subsequent intervals may be short *because* the index child died?

To avoid the possibility of reverse causality, we consider whether the woman became pregnant again or gave birth *before* the mortality subperiod under consideration. We find index children were much more likely to die during childhood (RR=2.33) if the mother was pregnant again by the time the index child was a year old. We find no additional significant effect of the woman actually giving birth again before the index

child's first birthday, but this is a rare event. Hence we do see a significant effect of short subsequent interpregnancy intervals.

8) To what extent do the effects of short intervals on infant and child mortality appear to be due to maternal depletion? To what extent to they appear to be due to competition among closely spaced siblings?

A number of the relationships we find in our analyses of infant and child mortality are consistent with the maternal depletion hypothesis, as are some we find for maternal morbidity, discussed below. We see that short inter-outcome intervals are more detrimental when they follow a live birth or stillbirth than when they follow a preceding miscarriage or abortion. Because of their longer gestation, live births and stillbirths should be more depleting than miscarriages or abortions. The effects of short inter-outcome intervals are greatest when the preceding outcome was a live birth. The breastfeeding that follows a live birth leads to further maternal depletion (and recall that prolonged breastfeeding is very common in Bangladesh). Furthermore, if the child born in the preceding pregnancy is still alive at the time of the index child's birth, he or she will compete with the index child for the family's resources – thus lending some support to the competition hypothesis – though we have found the interval effects are even greater if the preceding live birth died than if it survived, which is not consistent with the competition hypothesis. The depletion hypothesis is further supported by our finding that effects are greatest for the shortest intervals (which allow the smallest time for recuperation from the previous pregnancy) and in the neonatal period, when physiological factors, such as maternal depletion, are most likely to play a role.

The fact that the most pernicious intervals become longer as the child ages is consistent with competition, because children who are 2-3 years older than the index child may be as or more competitive for the family's time and resources as "older" siblings that are even closer in age to the index child. However, as noted above, the fact that interval effects are greater if the preceding live birth died than if it survived is not consistent with the competition hypothesis, but instead appears to reflect a higher family-level risk for all children in a family. Future research should attempt to control for this unobserved family-level heterogeneity.

9) Does the interval between the preceding pregnancy outcome and the conception of the index pregnancy affect the *outcome* of the index pregnancy (i.e., whether it results in a live birth or not) and the duration of the gestation of the index pregnancy, e.g., whether the baby is born prematurely?

The duration of an interpregnancy interval not only affects the survival of children born at the end of a pregnancy, it also affects whether the pregnancy results in a live birth. Short interpregnancy intervals are strongly associated with a very large increase in the odds ratio of a non-live birth outcome. The odds of having an induced abortion is 10 times that of having a live birth when the woman becomes pregnant within 6 months of the preceding pregnancy outcome. This suggests that many of the women who became pregnant within 6 months of the preceding pregnancy did not intend to do so and opted for an abortion to terminate the pregnancy. The odds of having a miscarriage or a stillbirth after an interpregnancy interval of less than 6 months are also elevated relative to having a live birth (OR=5.8 and OR=2.3, respectively).

Short preceding interpregnancy intervals (less than nine months) are also associated with shorter gestation of pregnancy (i.e., more premature births) for live births and stillbirths (and interpregnancy intervals of 9-14 months in duration are associated with earlier induced abortions).

10) How does the length of the interpregnancy interval preceding a pregnancy affect the woman's likelihood of morbidity during that pregnancy and her chance of dying from pregnancy-related causes? Are the interval effects on maternal outcomes U-shaped? I.e., are both too-short and too-long intervals pernicious?

Women with short interpregnancy intervals (<6 months or 6-14 months) have a significantly higher risk of pre-eclampsia, high blood pressure, and premature rupture of membranes compared with those with an interval of 27-50 months. A preceding interpregnancy of less than six months duration is associated with a somewhat elevated risk of maternal mortality compared to intervals of 27-50 months, but the relative risk (RR=1.58 without controls and OR=1.28 with controls) is not statistically significant.

Women with very long interpregnancy intervals (75+ months) have a significantly higher risk of pre-eclampsia, proteinuria, high blood pressure, and edema compared to women with intervals of 27-50 months. Very long interpregnancy intervals are also associated with significantly higher risks of maternal mortality. An interpregnancy

interval of 75 months or longer is associated with twice the mortality risk as an interval of 27-50 months.

We also find higher risks of pre-eclampsia, proteinuria, premature rupture of membranes, edema, and of maternal mortality associated with first pregnancies. The risk of maternal mortality associated with the first pregnancy is especially high for older women. (The risk of anemia during pregnancy is significantly lower for first pregnancies than higher-order ones and does not vary significantly with the length of the preceding interpregnancy interval.)

Hence we find that both very short and very long interpregnancy intervals are dangerous for women's health, as are first pregnancies, especially to older women. For pre-eclampsia and premature rupture of membranes, shorter intervals have a higher risk than longer ones, whereas for high blood pressure and maternal mortality, very long intervals have a higher risk than shorter ones.

The strong associations that we find of very long intervals and late childbearing with maternal mortality and some morbidities (high blood pressure, anemia [older age only], and edema) may reflect the fact that women who have difficulty becoming pregnant may have health problems that also lead to higher risk of morbidity and mortality. If they do become pregnant, such women merit special attention.

It is worth noting also that once we control for parity and the other independent variables we consider, we do not find significantly higher maternal morbidity or mortality for very young women or for high parity (once age is controlled), with the exception or anemia for the latter.

11) Do the effects of intervals on infant, child, and maternal health and survival remain when those of other potentially confounding variables (e.g., mother's age and education) are controlled?

Adding controls for demographic and socioeconomic factors reduces the relative risk associated with short inter-outcome intervals on infant and child mortality, but the effects of short intervals remain statistically significant nonetheless. The sizes of the reductions become larger as the child ages. That is, the reductions are relatively small in the earlier neonatal period, are somewhat larger in the rest of the first year of life, and are largest in the childhood period. After age one, when other variables are controlled,

preceding inter-outcome intervals of less than 18 months are no longer associated with significant reductions in the risk of mortality compared to intervals 3-5 years in length, but intervals of 18-35 months are still associated with a significantly increased risk of mortality (of around 20-30%). Most of the socioeconomic and demographic variables that we consider do have statistically significant effects on infant and child mortality.

Controlling for socioeconomic and demographic factors reduces somewhat the effect of short interpregnancy intervals on maternal mortality (though the effects are not statistically significant even without controls), and they also reduce somewhat the deleterious effects of very long intervals (75+ months), though the effect long intervals remain sizable and significant even after other variables are controlled.

Controlling for socioeconomic and demographic factors has relatively little effect on the estimates of the effects of intervals on most morbidities, though it does sometimes make differences that were statistically significant become insignificant. The largest differences between controlling and not controlling for other factors are seen for bleeding, premature rupture of membranes, and anemia. For bleeding, the interval effects are not statistically significant either without or with controls. For premature rupture of membranes and anemia, effects that were significant without controls become insignificant when other variables are controlled.

12) How do the magnitudes of the health risks associated with "high-risk" intervals compare to those for other explanatory variables associated with a higher risk of poor maternal, infant, and outcomes?

The magnitudes of the risks associated with "high-risk" intervals are large compared to those for other explanatory variables associated with a high risk of infant or child mortality, especially during the first month of life. Babies born less than 15 months after a preceding pregnancy outcome have an increased risk of early neonatal mortality that is 3.0 times that of the lowest-risk group (three-to-five-year inter-outcome intervals). By contrast, for the next highest-risk factor – young maternal age – we find that mothers who are less than 18 years old have an increased risk of first-week mortality of 1.7 relative to the lowest-risk age category (25-29 year old women). In the post-neonatal period and childhood, the adverse effects of low socioeconomic status and no education on mortality are larger in magnitude than the effect of short intervals.

13) Do the effects of intervals differ across subgroups of the population? Are there certain subgroups for whom effects are larger than others?

Our analyses of interactions of very short and very long intervals with key explanatory variables did not reveal any subgroups for whom effects were significantly greater than the others. Hence our analyses provide no indications that programs designed to reduce the incidence of intervals that are unhealthy, short or long, should focus on particular types of women.

14) What are the characteristics of the women who have the intervals lengths associated with poorer pregnancy, infant, child, and maternal outcomes?

Pregnancies following short inter-outcome intervals (<36 months) are more likely to be to women who live in the Comparison Area of Matlab. This suggests that women in the MCH-FP Area are better able to use contraception (more often and more effectively) to control the spacing of their pregnancies.

Short inter-outcome intervals are also more likely to occur for younger women and those whose preceding pregnancy ended in a non-live birth. Over half (57.3 percent) of the inter-outcome intervals that were less than 15 months in length began with a non-live birth, the majority of then miscarriages. It appears that these women want another child soon and become pregnant again as soon as possible to "replace" the pregnancy they have just lost. This may also reflect the fact that women with previous non-live births are able to become pregnant again sooner than those with live births because they were not breastfeeding.

Very long inter-outcome intervals are more common in the MCH-FP Area of Matlab. And very long interbirth intervals are much more likely if there was an intervening non-live birth. Nearly 21 percent of the women with very long interbirth intervals (84 months or more) had at least one intervening non-live birth.

Other conclusions and implications are presented and discussed at the end of Chapters IV and V. It is worth reiterating that more than half (57 percent) of all inter-outcome intervals of known duration in our data are less than 36 months in length. Since intervals of less than 36 months are associated with higher levels of infant and child

mortality and some maternal morbidities, there is plenty of opportunity in Bangladesh to reduce these adverse health outcomes by improving the spacing of pregnancies. Our simulations showed that the rates of infant and child mortality would be 5.8-9.4 percent lower if all inter-outcome intervals were 3-5 years in duration. Furthermore, reducing the incidence of short intervals will help reduce fertility rates in Bangladesh.

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APPENDICES

Appendix Table 1. Mean of all Explanatory Variables (n=142,773)

	Proportion in the sample
Inter-outcome Interval Duration	
IOI<15 months	0.07
IOI: 15-17 months	0.03
IOI: 18-23 months	0.07
IOI: 24-35 months	0.18
IOI: 36-59 months	0.18
IOI: 60-83 months	0.06
IOI: 84 plus months	0.03
IOI unknown	0.16
Duration of Pregnancy Gestation	
Gestation <30 weeks	0.02
Gestation 30-31 weeks	0.03
Gestation 32-33 weeks	0.05
Gestation 34-35 weeks	0.10
Gestation 36-37 weeks	0.15
Gestation 38-39 weeks	0.09
Gestation 40 plus weeks	0.03
Gestation unknown	0.53
Area	
Comparison Area	0.54
MCH-FP	0.46
Wantedness Status	
Not Wanted	0.01
Wanted (RC)	0.15
Wantedness unknown	0.84
Birth Parity	
First Birth	0.28
Parity 2-3	0.37
Parity 4-7	0.30
Parity 8 plus	0.05
Maternal Education	
Mother's Ed: 0 years	0.50
Mother's Ed: 1-5 years	0.30
Mother's Ed: 6-10 years	0.16
Mother's Ed: 11-16 years	0.02
Mother's Ed unknown	0.02
Father's Education	
Father's Ed: 0 years	0.23
Father's Ed: 1-5 years	0.29
Father's Ed: 6-10 years	0.17
Father's Ed: 11-16 years	0.05
Father's Ed unknown	0.25

Maternal Age	
Mother's Age <18	0.03
Mother's Age: 18-19	0.08
Mother's Age: 20-24	0.33
Mother's Age: 25-29	0.28
Mother's Age: 30-34	0.17
Mother's Age: 35 plus	0.12
Gender[34]	
Female	0.43
Male	0.45
Religion	
Non-Muslim	0.11
Muslim	0.89
Household Space Size	
House Size: Smallest Quartile	0.29
House Size 2nd Quartile	0.29
House Size 3rd Quartile	0.13
House Size Largest Quartile	0.04
House Size unknown	0.04
Preceding Pregnancy Outcome	
Preceding Outcome Live Birth	0.93
Preceding Outcome Abortion	0.01
Preceding Outcome Miscarriage	0.04
Preceding Outcome Stillbirth	0.02
Year	
Year 1982-1986	0.25
Year 1987-1991	0.26
Year 1992-1996	0.22
Year 1997-1999	0.13
Year 2000-2002	0.14
Month of Outcome	
January	0.09
February	0.07
March	0.07
April	0.07
May	0.07
June	0.06
July	0.07
August	0.08
September	0.09
October	0.12
November	0.12
December	0.11

[34] Gender of child is only known for live pregnancy outcomes. Thus, these numbers do not add to 1.0.

Appendix Table 2a. Results of Cox Proportional Hazards Model of First-Week Mortality: Interbirth vs. Inter-Outcome Intervals (n=125,720)

	RR	Std. Err.	RR	Std. Err.	RR	Std. Err.
First Birth	2.21	0.12 ***	1.84	0.08 ***	1.87	0.08 ***
Interbirth Interval (IBI) Duration						
IBI<15 months	3.90	0.32 ***				
IBI: 15-17 months	1.77	0.24 ***				
IBI: 18-23 months	1.50	0.13 ***				
IBI: 24-35 months	1.07	0.07				
IBI: 36-59 months (RC)	1.00	(--)				
IBI: 60-83 months	1.09	0.10				
IBI: 84 plus months	1.34	0.15 *				
IBI unknown	1.34	0.08 ***				
Inter-Outcome Interval (IOI) Duration						
IOI<15 months			2.05	0.12 ***	1.85	0.11 ***
IOI: 15-17 months			1.37	0.14 **	1.28	0.13 *
IOI: 18-23 months			1.24	0.09 **	1.11	0.08
IOI: 24-35 months			0.93	0.05	0.84	0.05 ***
IOI: 36-59 months (RC)			1.00	(--)	1.00	(--)
IOI: 60-83 months			0.89	0.08	1.02	0.10
IOI: 84 plus months			1.03	0.13	1.14	0.14
IOI unknown			1.16	0.06 **	1.04	0.06
Duration of Pregnancy Gestation						
Gestation <30 weeks					8.92	0.76 ***
Gestation 30-31 weeks					4.60	0.41 ***
Gestation 32-33 weeks					2.58	0.23 ***
Gestation 34-35 weeks					1.47	0.13 ***
Gestation 36-37 weeks (RC)					1.00	(--)
Gestation 38-39 weeks					1.09	0.11
Gestation 40 plus weeks					1.65	0.19 ***
Gestation unknown					2.71	0.18 ***

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 2b. Results of Cox Proportional Hazards Model of Late Neonatal Mortality (weeks 2-4): Interbirth vs. Inter-Outcome Intervals (n=121,936)

	RR	Std. Err.	RR	Std. Err.	RR	Std. Err.
First Birth	2.25	0.18 ***	1.83	0.11 ***	1.87	0.13 ***
Interbirth Interval (IBI) Duration						
IBI<15 months	3.31	0.44 ***				
IBI: 15-17 months	2.02	0.38 ***				
IBI: 18-23 months	1.74	0.21 ***				
IBI: 24-35 months	1.62	0.15 ***				
IBI: 36-59 months (RC)	1.00	(--)				
IBI: 60-83 months	0.72	0.12 *				
IBI: 84 plus months	0.93	0.19				
IBI unknown	1.83	0.16 ***				
Inter-Outcome Interval (IOI) Duration						
IOI<15 months			1.67	0.16 ***	1.50	0.15 ***
IOI: 15-17 months			1.43	0.21 *	1.32	0.20 +
IOI: 18-23 months			1.42	0.14 **	1.25	0.13 *
IOI: 24-35 months			1.36	0.10 ***	1.20	0.10 *
IOI: 36-59 months (RC)			1.00	(--)	1.00	(--)
IOI: 60-83 months			0.59	0.10 **	0.69	0.12 *
IOI: 84 plus months			0.76	0.16	0.87	0.19
IOI unknown			1.53	0.12 ***	1.38	0.11 ***
Duration of Pregnancy Gestation						
Gestation <30 weeks					5.41	0.79 ***
Gestation 30-31 weeks					3.77	0.53 ***
Gestation 32-33 weeks					2.51	0.33 ***
Gestation 34-35 weeks					1.74	0.21 ***
Gestation 36-37 weeks (RC)					1.00	(--)
Gestation 38-39 weeks					0.85	0.13
Gestation 40 plus weeks					1.00	0.21
Gestation unknown					3.02	0.29 ***

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 2c. Results of Cox Proportional Hazards Model of Post-neonatal Mortality (between day 29 and 365): Interbirth vs. Inter-Outcome Intervals (n=119,718)

	RR	Std. Err.	RR	Std. Err.	RR	Std. Err.
First Birth	1.63	0.09 ***	1.41	0.06 ***	1.43	0.07 ***
Interbirth Interval (IBI) Duration						
IBI<15 months	2.28	0.22 ***				
IBI: 15-17 months	2.25	0.26 ***				
IBI: 18-23 months	1.93	0.14 ***				
IBI: 24-35 months	1.33	0.08 ***				
IBI: 36-59 months (RC)	1.00	(--)				
IBI: 60-83 months	0.77	0.08 *				
IBI: 84 plus months	0.97	0.12				
IBI unknown	1.73	0.10 ***				
Inter-Outcome Interval (IOI) Duration						
IOI<15 months			1.48	0.10 ***	1.39	0.10 ***
IOI: 15-17 months			1.69	0.16 ***	1.60	0.15 ***
IOI: 18-23 months			1.66	0.11 ***	1.53	0.10 ***
IOI: 24-35 months			1.19	0.06 **	1.10	0.06
IOI: 36-59 months (RC)			1.00	(--)	1.00	(--)
IOI: 60-83 months			0.63	0.07 ***	0.69	0.07 ***
IOI: 84 plus months			0.92	0.12	0.99	0.13
IOI unknown			1.56	0.08 ***	1.46	0.08 ***
Duration of Pregnancy Gestation						
Gestation <30 weeks					2.39	0.26 ***
Gestation 30-31 weeks					2.15	0.20 ***
Gestation 32-33 weeks					1.65	0.13 ***
Gestation 34-35 weeks					1.09	0.08
Gestation 36-37 weeks (RC)					1.00	(--)
Gestation 38-39 weeks					0.89	0.08
Gestation 40 plus weeks					1.00	0.12
Gestation unknown					1.74	0.09 ***

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 2d. Results of Cox Proportional Hazards Model of Child Mortality: Interbirth vs. Inter-Outcome Intervals (n=110,191)

	RR	Std. Err.	RR	Std. Err.	RR	Std. Err.
First Birth	0.96	0.06	0.90	0.05 +	0.90	0.05 +
Interbirth Interval (IBI) Duration						
IBI<15 months	1.40	0.17 **				
IBI: 15-17 months	1.29	0.19 +				
IBI: 18-23 months	1.70	0.13 ***				
IBI: 24-35 months	1.54	0.09 ***				
IBI: 36-59 months	1.00	(--)				
IBI: 60-83 months	0.63	0.07 ***				
IBI: 84 plus months	0.72	0.12 *				
IBI unknown	2.26	0.12 ***				
Inter-Outcome Interval (IOI) Duration						
IOI<15 months			1.24	0.10 *	1.17	0.10 +
IOI: 15-17 months			1.18	0.15	1.12	0.14
IOI: 18-23 months			1.55	0.12 ***	1.44	0.11 ***
IOI: 24-35 months			1.48	0.08 ***	1.37	0.08 **
IOI: 36-59 months (RC)			1.00	(--)	1.00	(--)
IOI: 60-83 months			0.64	0.07 ***	0.69	0.08 ***
IOI: 84 plus months			0.76	0.13 +	0.81	0.13
IOI unknown			2.25	0.12 ***	2.18	0.12 ***
Duration of Pregnancy Gestation						
Gestation <30 weeks					1.13	0.16
Gestation 30-31 weeks					1.07	0.13
Gestation 32-33 weeks					1.16	0.11
Gestation 34-35 weeks					0.92	0.08
Gestation 36-37 weeks (RC)					1.00	(--)
Gestation 38-39 weeks					0.80	0.08 *
Gestation 40 plus weeks					1.07	0.13
Gestation unknown					1.54	0.09 ***

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 3a. Results of Cox proportional hazards model of first-week mortality: Effects of inter-outcome intervals with and without controls for other explanatory variables (n=125,720)

	RR	Std. Err.		RR	Std. Err.	
First Birth	2.02	0.09	***	1.89	0.11	***
Inter-outcome Interval Duration						
IOI<15 months	3.67	0.29	***	3.03	0.25	***
IOI: 15-17 months	1.45	0.17	**	1.32	0.15	*
IOI: 18-23 months	1.32	0.11	**	1.16	0.09	+
IOI: 24-35 months	0.99	0.06		0.90	0.06	+
IOI: 36-59 months (RC)	1.00	(--)		1.00	(--)	
IOI: 60-83 months	0.95	0.09		1.03	0.10	
IOI: 84 plus months	1.10	0.14		1.08	0.14	
IOI unknown	1.23	0.07	***	1.15	0.08	*
Preceding Pregnancy Outcome						
Preceding Outcome Live Birth (RC)	1.00			1.00	(--)	
Preceding Outcome Abortion	0.38	0.14	**	0.77	0.18	
Preceding Outcome Miscarriage	0.34	0.06	***	1.16	0.15	
Preceding Outcome Stillbirth	0.44	0.10	***	1.16	0.18	
Inter-outcome Interval * Non-live Prec. Outcome						
Interaction: IOI<15 months * Prec. outcome abortion	0.70	0.16		0.39	0.14	**
Interaction: IOI<15 months * Prec. outcome miscarriage	1.02	0.13		0.35	0.06	***
Interaction: IOI<15 months * Prec. outcome stillbirth	1.00	0.16		0.45	0.10	***
Duration of Pregnancy Gestation						
Gestation <30 weeks				8.62	0.75	***
Gestation 30-31 weeks				4.51	0.41	***
Gestation 32-33 weeks				2.51	0.22	***
Gestation 34-35 weeks				1.44	0.13	***
Gestation 36-37 weeks (RC)				1.00	(--)	
Gestation 38-39 weeks				1.10	0.11	
Gestation 40 plus weeks				1.65	0.19	***
Gestation unknown				2.61	0.29	***
Area						
Comparison Area (RC)				1.00	(--)	
MCH-FP Area				0.95	0.09	
Interaction: Gestation unknown* MCHFP				2.10	0.26	***
Wantedness Status						
Not Wanted			1.84	0.27		***
Wanted (RC)			1.00	(--)		
Wantedness unknown			0.86	0.06		*
Birth Parity						
Parity 2-3 (RC)				1.00	(--)	
Parity 4-7				1.01	0.06	
Parity 8 plus				1.35	0.14	**
Maternal Education						
Mother's Ed: 0 years (RC)				1.00	(--)	
Mother's Ed: 1-5 years				0.96	0.04	

Mother's Ed: 6-10 years	0.81	0.05 ***
Mother's Ed: 11-16 years	0.82	0.13
Mother's Ed unknown	0.97	0.11
Father's Education		
Father's Ed: 0 years (RC)	1.00	(--)
Father's Ed: 1-5 years	0.94	0.05
Father's Ed: 6-10 years	0.97	0.05
Father's Ed: 11-16 years	0.99	0.09
Father's Ed unknown	0.92	0.05
Maternal Age		
Mother's Age <18	1.75	0.16 ***
Mother's Age: 18-19	1.36	0.10 ***
Mother's Age: 20-24	1.05	0.06
Mother's Age: 25-29 (RC)	1.00	(--)
Mother's Age: 30-34	1.04	0.06
Mother's Age: 35 plus	1.06	0.09
Gender		
Female	0.84	0.03 ***
Male (RC)	1.00	(--)
Religion		
Non-Muslim	1.26	0.06 ***
Muslim (RC)	1.00	(--)
Household Space Size		
House Size Smallest Quartile (RC)	1.00	(--)
House Size 2nd Quartile	0.98	0.04
House Size 3rd Quartile	1.00	0.05
House Size Largest Quartile	0.89	0.06 +
House Size unknown	1.00	0.09
Year		
Year 1982-1986	0.86	0.07 +
Year 1987-1991	0.91	0.07
Year 1992-1996	0.90	0.07
Year 1997-1999	0.80	0.07 **
Year 2000-2002 (RC)	1.00	(--)
Month of Birth		
January	1.00	0.07
February	0.88	0.07
March	0.74	0.06 ***
April	0.85	0.07 +
May	0.85	0.07 +
June	0.89	0.08
July	0.93	0.07
August	1.04	0.08
September	1.03	0.07
October	0.99	0.07
November	0.89	0.06 +
December (RC)	1.00	(--)

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 3b. Results of Cox proportional hazards model of late neonatal mortality: Effects of inter-outcome intervals with and without controls for other explanatory variables (n=121,936)

	RR	Std. Err.	RR	Std. Err.
First Birth	2.04	0.14***	1.78	0.16***
Inter-outcome Interval Duration				
IOI<15 months	3.02	0.39***	2.23	0.30***
IOI: 15-17 months	1.81	0.30***	1.44	0.24*
IOI: 18-23 months	1.62	0.18**	1.27	0.14*
IOI: 24-35 months	1.48	0.12***	1.18	0.10+
IOI: 36-59 months (RC)	1.00	(--)	1.00	(--)
IOI: 60-83 months	0.64	0.11**	0.85	0.15
IOI: 84 plus months	0.82	0.18	1.11	0.25
IOI unknown	1.64	0.13***	1.13	0.11
Preceding Pregnancy Outcome				
Preceding Outcome Live Birth (RC)	1.00	(--)	1.00	(--)
Preceding Outcome Abortion	0.52	0.23	1.26	0.33
Preceding Outcome Miscarriage	0.71	0.22	0.63	0.15*
Preceding Outcome Stillbirth	0.40	0.16*	0.94	0.22
Inter-outcome Interval * Non-live Prec. Outcome				
Interaction: IOI<15 months * Prec. outcome abortion	0.98	0.26	0.50	0.22
Interaction: IOI<15 months * Prec. outcome miscarriage	0.52	0.12**	0.75	0.23
Interaction: IOI<15 months * Prec. outcome stillbirth	0.72	0.18	0.36	0.14*
Duration of Pregnancy Gestation				
Gestation <30 weeks			4.59	0.68***
Gestation 30-31 weeks			3.36	0.47***
Gestation 32-33 weeks			2.33	0.30***
Gestation 34-35 weeks			1.63	0.20***
Gestation 36-37 weeks (RC)			1.00	(--)
Gestation 38-39 weeks			0.92	0.14
Gestation 40 plus weeks			1.01	0.21
Gestation unknown			2.58	0.49***
Area				
Comparison Area (RC)			1.00	(--)
MCH-FP Area			1.13	0.26
Interaction: Gestation unknown* MCHFP			0.91	0.15
Wantedness Status				
Not Wanted			1.62	0.44+
Wanted (RC)				
Wantedness unknown			0.86	0.10
Birth Parity				
Parity 2-3 (RC)			1.00	(--)
Parity 4-7			0.99	0.08
Parity 8 plus			1.27	0.18+
Maternal Education				
Mother's Ed: 0 years (RC)			1.00	(--)
Mother's Ed: 1-5 years			0.87	0.05*

Mother's Ed: 6-10 years	0.73	0.06 ***
Mother's Ed: 11-16 years	0.39	0.14 **
Mother's Ed unknown	1.04	0.14
Father's Education		
Father's Ed: 0 years (RC)	1.00	(--)
Father's Ed: 1-5 years	0.92	0.07
Father's Ed: 6-10 years	0.94	0.08
Father's Ed: 11-16 years	0.67	0.11 *
Father's Ed unknown	0.94	0.07
Maternal Age		
Mother's Age <18	2.17	0.29 ***
Mother's Age: 18-19	1.44	0.15 **
Mother's Age: 20-24	1.29	0.10 **
Mother's Age: 25-29 (RC)	1.00	(--)
Mother's Age: 30-34	1.22	0.11 *
Mother's Age: 35 plus	1.09	0.13
Gender		
Female	0.95	0.05
Male (RC)	1.00	(--)
Religion		
Non-Muslim	1.25	0.09
Muslim (RC)	1.00	(--)
Household Space Size		
House Size Smallest Quartile (RC)	1.00	(--)
House Size 2nd Quartile	0.93	0.06
House Size 3rd Quartile	0.99	0.07
House Size Largest Quartile	0.90	0.08
House Size unknown	0.85	0.13
Year		
Year 1982-1986	1.65	0.23 ***
Year 1987-1991	1.45	0.20 **
Year 1992-1996	1.01	0.14
Year 1997-1999	0.79	0.12
Year 2000-2002 (RC)	1.00	(--)
Month of Birth		
January	0.95	0.09
February	0.73	0.08 **
March	0.62	0.07 ***
April	0.56	0.07 ***
May	0.68	0.08 **
June	0.63	0.08 ***
July	0.66	0.08 ***
August	0.71	0.08 **
September	0.79	0.08 *
October	0.81	0.07 *
November	0.81	0.07 *
December (RC)	1.00	(--)

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 3c. Results of Cox proportional hazards model of post-neonatal mortality: Effects of inter-outcome intervals with and without controls for other explanatory variables (n=119,718)

	RR	Std. Err.	RR	Std. Err.
First Birth	1.50	0.07 ***	1.63	0.10 ***
Inter-outcome Interval Duration				
IOI<15 months	2.16	0.21 ***	1.80	0.18 ***
IOI: 15-17 months	2.03	0.21 ***	1.78	0.19 ***
IOI: 18-23 months	1.82	0.13 ***	1.52	0.11 ***
IOI: 24-35 months	1.25	0.07 ***	1.04	0.06
IOI: 36-59 months (RC)	1.00	(--)	1.00	(--)
IOI: 60-83 months	0.66	0.07 ***	0.81	0.09 +
IOI: 84 plus months	0.96	0.13	1.24	0.17
IOI unknown	1.61	0.09 ***	1.13	0.07 +
Preceding Pregnancy Outcome				
Preceding Outcome Live Birth (RC)	1.00		1.00	(--)
Preceding Outcome Abortion	0.41	0.11 **	0.49	0.13 **
Preceding Outcome Miscarriage	0.63	0.09 **	0.68	0.10 **
Preceding Outcome Stillbirth	0.85	0.13	0.97	0.15
Inter-outcome Interval * Non-live Prec. Outcome				
Interaction: IOI<15 months * Prec. outcome abortion	1.24	0.48	1.15	0.45
Interaction: IOI<15 months * Prec. outcome miscarriage	0.76	0.15	0.78	0.16
Interaction: IOI<15 months * Prec. outcome stillbirth	0.80	0.19	0.73	0.17
Duration of Pregnancy Gestation				
Gestation <30 weeks			1.96	0.21 ***
Gestation 30-31 weeks			1.87	0.17 ***
Gestation 32-33 weeks			1.51	0.12 ***
Gestation 34-35 weeks			1.01	0.08
Gestation 36-37 weeks (RC)			1.00	(--)
Gestation 38-39 weeks			0.97	0.08
Gestation 40 plus weeks			1.01	0.12
Gestation unknown			1.57	0.21 **
Area				
Comparison Area (RC)			1.00	(--)
MCH-FP Area			1.07	0.14
Interaction: Gestation unknown* MCHFP			1.23	0.20
Wantedness Status				
Not Wanted			0.95	0.18
Wanted (RC)			1.00	(--)
Wantedness unknown			0.95	0.07
Birth Parity				
Parity 2-3 (RC)			1.00	(--)
Parity 4-7			1.07	0.06
Parity 8 plus			1.52	0.14 ***
Maternal Education				
Mother's Ed: 0 years (RC)			1.00	(--)
Mother's Ed: 1-5 years			0.89	0.04 **

Mother's Ed: 6-10 years	0.66	0.04 ***
Mother's Ed: 11-16 years	0.51	0.11 **
Mother's Ed unknown	0.76	0.09 *
Father's Education		
Father's Ed: 0 years (RC)	1.00	(--)
Father's Ed	0.97	0.05
Father's Ed	0.90	0.05 +
Father's Ed: 11-16 years	0.94	0.09
Father's Ed unknown	0.99	0.05
Maternal Age	0.96	0.05
Mother's Age <18	1.35	0.14 **
Mother's Age: 18-19	1.09	0.08
Mother's Age: 20-24	1.09	0.06
Mother's Age: 25-29 (RC)	1.00	(--)
Mother's Age: 30-34	1.12	0.06 *
Mother's Age: 35 plus	1.24	0.09 **
Gender		
Female	1.04	0.03
Male (RC)	1.00	(--)
Religion		
Non-Muslim	1.05	0.06
Muslim (RC)	1.00	(--)
Household Space Size		
House Size Smallest Quartile (RC)	1.00	(--)
House Size 2nd Quartile	0.89	0.04 **
House Size 3rd Quartile	0.90	0.04 *
House Size Largest Quartile	0.79	0.05 ***
House Size unknown	0.86	0.09
Year		
Year 1982-1986	2.15	0.22 ***
Year 1987-1991	1.89	0.19 ***
Year 1992-1996	1.41	0.14 **
Year 1997-1999	1.16	0.12
Year 2000-2002 (RC)	1.00	(--)
Month of Birth		
January	1.06	0.08
February	0.94	0.07
March	0.89	0.07
April	0.80	0.07 **
May	0.72	0.06 ***
June	0.71	0.07 ***
July	0.99	0.08
August	0.87	0.07 +
September	0.88	0.06 +
October	1.03	0.07
November	1.06	0.07
December (RC)	1.00	(--)

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 3d. Results of Cox proportional hazards model of child mortality: Effects of inter-outcome intervals with and without controls for other explanatory variables (n=110,191)

	RR	Std. Err.	RR	Std. Err.
First Birth	0.93	0.05	0.99	0.07
Inter-outcome Interval Duration				
IOI<15 months	1.39	0.17 **	1.11	0.14
IOI: 15-17 months	1.37	0.18 *	1.10	0.14
IOI: 18-23 months	1.65	0.13 ***	1.29	0.10 **
IOI: 24-35 months	1.52	0.09 ***	1.21	0.07 **
IOI: 36-59 months (RC)	1.00	(--)	1.00	(--)
IOI: 60-83 months	0.65	0.08 ***	0.78	0.09 *
IOI: 84 plus months	0.77	0.13	0.99	0.17
IOI unknown	2.27	0.12 ***	1.39	0.09 ***
Preceding Pregnancy Outcome				
Preceding Outcome Live Birth (RC)	1.00	(--)	1.00	(--)
Preceding Outcome Abortion	3.10	1.34 **	0.43	0.15 *
Preceding Outcome Miscarriage	1.23	0.29	0.71	0.12 *
Preceding Outcome Stillbirth	0.96	0.28	0.95	0.18
Inter-outcome Interval * Non-live Preg. Outcome				
Interaction: IOI<15 months * Prec. outcome abortion	0.37	0.12 **	2.67	1.16 *
Interaction: IOI<15 months * Prec. outcome miscarriage	0.64	0.11 **	1.17	0.28
Interaction: IOI<15 months * Prec. outcome stillbirth	0.81	0.15	0.86	0.25
Duration of Pregnancy Gestation				
Gestation <30 weeks			0.90	0.13
Gestation 30-31 weeks			0.92	0.11
Gestation 32-33 weeks			1.06	0.10
Gestation 34-35 weeks			0.86	0.07 +
Gestation 36-37 weeks (RC)			1.00	(--)
Gestation 38-39 weeks			0.86	0.08
Gestation 40 plus weeks			1.03	0.12
Gestation unknown			1.09	0.20
Area				
Comparison Area (RC)			1.00	(--)
MCH-FP Area			0.79	0.14
Interaction: Gestation unknown* MCHFP			1.20	0.26
Wantedness Status				
Not Wanted			1.11	0.23
Wanted (RC)			1.00	(--)
Wantedness unknown			0.92	0.08
Birth Parity				
Parity 2-3 (RC)			1.00	(--)
Parity 4-7			1.26	0.07 ***
Parity 8 plus			1.60	0.15 ***
Maternal Education				
Mother's Ed: 0 years (RC)			1.00	(--)
Mother's Ed: 1-5 years			0.70	0.03 ***

Mother's Ed: 6-10 years	0.57	0.04***
Mother's Ed: 11-16 years	0.44	0.12**
Mother's Ed unknown	0.75	0.09*
Father's Education		
Father's Ed: 0 years (RC)	1.00	(--)
Father's Ed: 1-5 years	0.95	0.05
Father's Ed: 6-10 years	0.87	0.06*
Father's Ed: 11-16 years	0.82	0.10+
Father's Ed unknown	0.99	0.05
Maternal Age		
Mother's Age <18	1.10	0.15
Mother's Age: 18-19	1.02	0.09
Mother's Age: 20-24	1.00	0.05
Mother's Age: 25-29 (RC)	1.00	(--)
Mother's Age: 30-34	1.03	0.06
Mother's Age: 35 plus	0.84	0.06*
Gender		
Female	1.49	0.05***
Male (RC)	1.00	(--)
Religion		
Non-Muslim	0.80	0.05**
Muslim (RC)	1.00	(--)
Household Space Size		
House Size Smallest Quartile (RC)	1.00	(--)
House Size 2nd Quartile	0.94	0.04
House Size 3rd Quartile	0.83	0.04***
House Size Largest Quartile	0.81	0.05**
House Size unknown	0.71	0.09**
Year		
Year 1982-1986	1.94	0.30***
Year 1987-1991	1.19	0.18
Year 1992-1996	1.00	0.15
Year 1997-1999	0.82	0.13
Year 2000-2002 (RC)	1.00	(--)
Month of Birth		
January	1.07	0.08
February	0.93	0.08
March	1.13	0.09
April	0.96	0.08
May	1.09	0.09
June	0.97	0.09
July	1.02	0.09
August	1.13	0.09
September	1.00	0.08
October	0.99	0.07
November	1.04	0.07
December (RC)	1.00	(--)

Subsequent Pregnancy and Birth		
Not Pregnant at 365 days (RC)	1.00	(--)
Pregnant at 365 days	2.33	0.15 ***
No Subsequent Birth at 365 days (RC)	1.00	(--)
Subsequent Birth at 365 days	1.33	0.48

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix 4a. Results of Cox Proportional Hazards Model of Early Post-Neonatal Mortality in the MCH-FP Area with and without Controls for Breastfeeding (n=56,075)

	RR	Std. Err.	RR	Std. Err.
First Birth	1.85	0.21***	1.85	0.21***
Inter-outcome Interval Duration				
IOI<15 months	1.93	0.34***	1.90	0.34***
IOI: 15-17 months	1.76	0.35**	1.84	0.37**
IOI: 18-23 months	1.60	0.23**	1.64	0.23***
IOI: 24-35 months	0.97	0.11	0.97	0.11
IOI: 36-59 months (RC)	1.00	(--)	1.00	(--)
IOI: 60-83 months	0.78	0.14	0.77	0.14
IOI: 84 plus months	1.29	0.29	1.21	0.27
IOI unknown	0.95	0.11	0.94	0.11
Preceding Pregnancy Outcome				
Preceding Outcome Live Birth (RC)	1.00	(--)	1.00	(--)
Preceding Outcome Abortion	0.33	0.24	0.31	0.22
Preceding Outcome Miscarriage	0.97	0.23	0.93	0.22
Preceding Outcome Stillbirth	0.72	0.24	0.71	0.24
Inter-outcome Interval * Non-live Preg. Outcome				
Interaction: IOI<15 months * Prec. outcome abortion	1.50	1.52	1.67	1.69
Interaction: IOI<15 months * Prec. outcome miscarriage	0.58	0.21	0.61	0.22
Interaction: IOI<15 months * Prec. outcome stillbirth	0.46	0.25	0.47	0.26
Duration of Pregnancy Gestation				
Gestation <30 weeks	2.39	0.31***	2.36	0.31***
Gestation 30-31 weeks	2.07	0.24***	2.03	0.23***
Gestation 32-33 weeks	1.65	0.17***	1.60	0.16***
Gestation 34-35 weeks	1.06	0.10	1.05	0.10
Gestation 36-37 weeks (RC)	1.00	(--)	1.00	(--)
Gestation 38-39 weeks	0.94	0.10	0.92	0.10
Gestation 40 plus weeks	1.09	0.16	1.10	0.16
Gestation unknown	2.34	0.30***	0.77	0.12+
Wantedness Status				
Not Wanted	0.91	0.22	0.83	0.20
Wanted (RC)	1.00	(--)	1.00	(--)
Wantedness unknown	0.71	0.08**	0.69	0.08**
Birth Parity				
Parity 2-3 (RC)	1.00	(--)	1.00	(--)
Parity 4-7	1.53	0.16***	1.58	0.16***
Parity 8 plus	2.98	0.55***	2.88	0.53***
Maternal Education				
Mother's Ed: 0 years (RC)	1.00	(--)	1.00	(--)
Mother's Ed: 1-5 years	0.82	0.06*	0.83	0.06*
Mother's Ed: 6-10 years	0.73	0.08**	0.73	0.08**
Mother's Ed: 11-16 years	0.61	0.20	0.51	0.17*
Mother's Ed unknown	0.60	0.13*	0.60	0.13*

Father's Education				
Father's Ed: 0 years (RC)	1.00	(--)	1.00	(--)
Father's Ed: 1-5 years	0.95	0.09	0.95	0.09
Father's Ed: 6-10 years	0.88	0.10	0.86	0.10
Father's Ed: 11-16 years	0.67	0.13 *	0.65	0.13 *
Father's Ed unknown	0.92	0.09	0.87	0.08
Maternal Age				
Mother's Age <18	1.67	0.31 **	1.56	0.29 *
Mother's Age: 18-19	1.22	0.17 *	1.22	0.17
Mother's Age: 20-24	1.24	0.12 *	1.23	0.12 *
Mother's Age: 25-29 (RC)	1.00	(--)	1.00	(--)
Mother's Age: 30-34	1.03	0.11	1.04	0.11
Mother's Age: 35 plus	0.76	0.12 +	0.75	0.12 +
Gender				
Female	0.95	0.06	0.95	0.06
Male (RC)	1.00	(--)	1.00	(--)
Religion				
Non-Muslim	1.15	0.10	1.10	0.10
Muslim (RC)	1.00	(--)	1.00	(--)
Household Space Size				
House Size Smallest Quartile (RC)	1.00	(--)	1.00	(--)
House Size 2nd Quartile	0.82	0.07 *	0.84	0.07 *
House Size 3rd Quartile	0.95	0.08	0.93	0.08
House Size Largest Quartile	0.89	0.10	0.91	0.10
House Size unknown	1.06	0.20	0.93	0.17
Year				
Year 1982-1986 (RC)				
Year 1987-1991	0.86	0.07 +	0.84	0.07 *
Year 1992-1996	0.52	0.07 ***	0.47	0.06 ***
Year 1997-1999	0.40	0.06 ***	0.34	0.05 ***
Year 2000-2002	0.40	0.06 ***	0.32	0.05 ***
Month of Birth				
January	1.31	0.17 *	1.36	0.18 *
February	1.13	0.16	1.15	0.17
March	1.06	0.15	1.08	0.16
April	0.98	0.15	1.00	0.15
May	0.57	0.10 **	0.58	0.11 **
June	0.59	0.11 **	0.61	0.11 **
July	0.89	0.13	0.89	0.13
August	0.74	0.11 *	0.75	0.11 +
September	0.71	0.11 *	0.74	0.11 *
October	1.00	0.13	1.07	0.14
November	1.13	0.14	1.18	0.15
December (RC)	1.00	(--)	1.00	(--)
Breastfeeding				
Breastfeeding in days until day 25			0.82	0.01 ***
Breastfeeding unknown			8.55	0.96 ***

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 4b. Results of Cox Proportional Hazards Model of Late Post-Neonatal Mortality in the MCH-FP Area with and without Controls for Breastfeeding (n=56,075)

	RR	Std. Err.	RR	Std. Err.
First Birth	1.84	0.32 **	1.79	0.31 **
Inter-outcome Interval Duration				
IOI<15 months	1.57	0.52	1.57	0.52
IOI: 15-17 months	1.68	0.59	1.66	0.58
IOI: 18-23 months	1.99	0.43 **	1.96	0.42 **
IOI: 24-35 months	1.59	0.27 **	1.58	0.27 **
IOI: 36-59 months (RC)	1.00	(--)	1.00	(--)
IOI: 60-83 months	1.39	0.34	1.38	0.33
IOI: 84 plus months	0.88	0.39	0.84	0.37
IOI unknown	1.35	0.24 +	1.32	0.23
Preceding Pregnancy Outcome				
Preceding Outcome Live Birth (RC)	1.00	(--)	1.00	(--)
Preceding Outcome Abortion	1.07	0.63	1.11	0.65
Preceding Outcome Miscarriage	0.29	0.17 *	0.29	0.17 *
Preceding Outcome Stillbirth	0.74	0.35	0.75	0.35
Inter-outcome Interval * Non-live Preg. Outcome				
Interaction: IOI<15 months * Prec. outcome abortion	0.00	0.00	0.00	0.00
Interaction: IOI<15 months * Prec. outcome miscarriage	1.10	0.91	1.10	0.91
Interaction: IOI<15 months * Prec. outcome stillbirth	0.47	0.42	0.47	0.42
Duration of Pregnancy Gestation				
Gestation <30 weeks	1.22	0.26	1.22	0.26
Gestation 30-31 weeks	1.28	0.23	1.28	0.23
Gestation 32-33 weeks	1.30	0.19 +	1.30	0.19 +
Gestation 34-35 weeks	0.89	0.12	0.89	0.12
Gestation 36-37 weeks (RC)	1.00	(--)	1.00	(--)
Gestation 38-39 weeks	1.02	0.15	1.01	0.15
Gestation 40 plus weeks	0.91	0.19	0.91	0.19
Gestation unknown	1.16	0.27	0.54	0.14 *
Wantedness Status				
Not Wanted	1.10	0.38	1.03	0.36
Wanted (RC)	1.00	(--)	1.00	(--)
Wantedness unknown	1.07	0.19	1.05	0.18
Birth Parity				
Parity 2-3 (RC)	1.00	(--)	1.00	(--)
Parity 4-7	1.23	0.19	1.26	0.19
Parity 8 plus	2.06	0.53 **	2.07	0.53 **
Maternal Education				
Mother's Ed: 0 years (RC)	1.00	(--)	1.00	(--)
Mother's Ed: 1-5 years	0.88	0.10	0.88	0.10
Mother's Ed: 6-10 years	0.51	0.10 ***	0.51	0.09 ***
Mother's Ed: 11-16 years	0.22	0.16 *	0.20	0.14 *
Mother's Ed unknown	0.57	0.20	0.56	0.19 +

Father's Education				
Father's Ed: 0 years (RC)	1.00	(--)	1.00	(--)
Father's Ed: 1-5 years	1.07	0.16	1.06	0.15
Father's Ed: 6-10 years	0.88	0.16	0.86	0.15
Father's Ed: 11-16 years	1.47	0.36	1.44	0.36
Father's Ed unknown	1.12	0.16	1.07	0.16
Maternal Age				
Mother's Age <18	0.94	0.31	0.91	0.30
Mother's Age: 18-19	1.13	0.24	1.15	0.24
Mother's Age: 20-24	1.11	0.16	1.12	0.16
Mother's Age: 25-29 (RC)	1.00	(--)	1.00	(--)
Mother's Age: 30-34	0.86	0.15	0.87	0.15
Mother's Age: 35 plus	1.19	0.24	1.19	0.24
Gender				
Female	1.28	0.12 **	1.27	0.12 *
Male (RC)	1.00	(--)	1.00	(--)
Religion				
Non-Muslim	0.86	0.12	0.84	0.12
Muslim (RC)	1.00	(--)	1.00	(--)
Household Space Size				
House Size Smallest Quartile (RC)	1.00	(--)	1.00	(--)
House Size 2nd Quartile	0.79	0.10 +	0.80	0.10 +
House Size 3rd Quartile	0.96	0.11	0.98	0.12
House Size Largest Quartile	0.67	0.12 *	0.69	0.12 *
House Size unknown	0.52	0.20 +	0.47	0.19 +
Year				
Year 1982-1986 (RC)				
Year 1987-1991	0.74	0.09 *	0.73	0.09 *
Year 1992-1996	0.59	0.11 **	0.56	0.11 **
Year 1997-1999	0.41	0.10 ***	0.40	0.10 ***
Year 2000-2002	0.47	0.11 **	0.42	0.10 ***
Month of Birth				
January	0.84	0.18	0.83	0.18
February	0.67	0.16	0.66	0.16 +
March	0.87	0.19	0.86	0.19
April	0.77	0.18	0.77	0.18
May	0.73	0.18	0.72	0.17
June	0.78	0.19	0.79	0.19
July	0.92	0.20	0.90	0.20
August	0.97	0.20	0.96	0.20
September	0.96	0.19	0.96	0.19
October	1.15	0.20	1.16	0.21
November	0.92	0.17	0.92	0.17
December (RC)	1.00	(--)	1.00	(--)
Breastfeeding				
Breastfeeding in days until day 165			0.98	0.00 ***
Breastfeeding unknown			4.19	0.92 ***

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 4c. Results of Cox Proportional Hazards Model of Mortality during the 12th – 18th month in the MCH-FP Area, with and without Controls for Breastfeeding and Immunizations (n=51,706)

	RR	Std. Err.		RR	Std. Err.		RR	Std. Err.	
First Birth	1.003	0.20		0.99	0.20		0.97	0.20	
Inter-outcome Interval Duration									
IOI<15 months	0.88	0.38		0.88	0.38		0.86	0.37	
IOI: 15-17 months	1.94	0.64	*	1.93	0.64	*	1.91	0.63	*
IOI: 18-23 months	1.15	0.31		1.13	0.31		1.12	0.31	
IOI: 24-35 months	1.11	0.21		1.10	0.21		1.10	0.21	
IOI: 36-59 months (RC)	1.00	(--)		1.00	(--)		1.00	(--)	
IOI: 60-83 months	0.61	0.19		0.60	0.19		0.60	0.18	+
IOI: 84 plus months	1.08	0.40		1.02	0.38		1.01	0.37	
IOI unknown	1.25	0.24		1.23	0.23		1.16	0.23	
Preceding Pregnancy Outcome									
Preceding Outcome Live Birth (RC)	1.00	(--)		1.00	(--)				
Preceding Outcome Abortion	1.14	0.82		1.18	0.85		1.18	0.85	
Preceding Outcome Miscarriage	0.55	0.29		0.55	0.29		0.55	0.29	
Preceding Outcome Stillbirth	0.46	0.33		0.46	0.33		0.46	0.33	
Inter-outcome Interval * Non-live Preg. Outcome									
Interaction: IOI<15 months * Prec. outcome abortion	0.00	0.00		0.00	0.00		0.00	0.00	
Interaction: IOI<15 months * Prec. outcome miscarriage	2.44	1.84		2.46	1.85		2.47	1.86	
Interaction: IOI<15 months * Prec. outcome stillbirth	1.85	2.01		1.86	2.02		1.84	2.01	
Duration of Pregnancy Gestation									
Gestation <30 weeks	1.01	0.29		1.00	0.28		1.01	0.29	
Gestation 30-31 weeks	1.14	0.26		1.12	0.25		1.12	0.26	
Gestation 32-33 weeks	1.26	0.22		1.25	0.22		1.25	0.22	
Gestation 34-35 weeks	0.89	0.14		0.89	0.14		0.89	0.14	
Gestation 36-37 weeks (RC)	1.00	(--)		1.00	(--)		1.00	(--)	
Gestation 38-39 weeks	1.14	0.20		1.13	0.19		1.13	0.19	
Gestation 40 plus weeks	1.18	0.26		1.19	0.26		1.18	0.26	
Gestation unknown	1.61	0.39	*	0.83	0.23		0.80	0.23	
Wantedness Status									
Not Wanted	1.18	0.43		1.15	0.42		1.15	0.42	
Wanted (RC)	1.00	(--)		1.00	(--)		1.00	(--)	
Wantedness unknown	0.96	0.20		0.94	0.19		0.95	0.19	
Birth Parity									
Parity 2-3 (RC)	1.00	(--)		1.00	(--)		1.00	(--)	
Parity 4-7	1.09	0.17		1.11	0.18		1.10	0.18	
Parity 8 plus	1.79	0.54	+	1.77	0.53	+	1.74	0.52	+
Maternal Education									
Mother's Ed: 0 years (RC)	1.00	(--)		1.00	(--)		1.00	(--)	
Mother's Ed: 1-5 years	0.70	0.10	*	0.70	0.10	**	0.70	0.10	*
Mother's Ed: 6-10 years	0.72	0.14		0.70	0.14	+	0.71	0.14	+
Mother's Ed: 11-16 years	0.55	0.34		0.51	0.31		0.52	0.31	
Mother's Ed unknown	0.89	0.29		0.88	0.29		0.88	0.29	

Father's Education						
Father's Ed: 0 years (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Father's Ed: 1-5 years	0.71	0.11 *	0.70	0.11 *	0.70	0.11 *
Father's Ed: 6-10 years	0.72	0.14 +	0.71	0.13 +	0.71	0.13 +
Father's Ed: 11-16 years	0.61	0.20	0.59	0.20	0.60	0.20
Father's Ed unknown	0.75	0.12 +	0.72	0.11 *	0.72	0.11 *
Maternal Age						
Mother's Age <18	0.91	0.36	0.90	0.36	0.87	0.35
Mother's Age: 18-19	0.78	0.21	0.77	0.21	0.76	0.20
Mother's Age: 20-24	0.84	0.13	0.84	0.13	0.83	0.13
Mother's Age: 25-29 (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Mother's Age: 30-34	0.88	0.15	0.88	0.15	0.88	0.15
Mother's Age: 35 plus	0.79	0.19	0.78	0.19	0.79	0.19
Gender						
Female	1.10	0.12	1.09	0.12	1.09	0.12
Male (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Religion						
Non-Muslim	0.86	0.14	0.84	0.14	0.85	0.14
Muslim (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Household Space Size						
House Size Smallest Quartile (RC)	1.00	(--)	1.00	(--)	1.00	(--)
House Size 2nd Quartile	1.08	0.15	1.10	0.15	1.10	0.15
House Size 3rd Quartile	0.93	0.13	0.94	0.14	0.94	0.14
House Size Largest Quartile	0.66	0.14 *	0.67	0.14 +	0.67	0.14 +
House Size unknown	0.78	0.29	0.72	0.27	0.73	0.27
Year						
Year 1982-1986 (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Year 1987-1991	0.56	0.09 ***	0.55	0.09 ***	0.62	0.11 **
Year 1992-1996	0.54	0.12 **	0.52	0.12 **	0.58	0.14 *
Year 1997-1999	0.49	0.13 **	0.48	0.12 **	0.55	0.15 *
Year 2000-2002	0.57	0.16 *	0.50	0.14 *	0.57	0.17 +
Month of Birth						
January	1.27	0.31	1.26	0.31	1.24	0.31
February	1.17	0.31	1.14	0.30	1.13	0.30
March	1.99	0.46 **	1.98	0.45 **	1.96	0.45 **
April	1.57	0.39 +	1.57	0.39 +	1.55	0.38 +
May	1.19	0.32	1.16	0.31	1.15	0.31
June	1.12	0.31	1.11	0.31	1.11	0.31
July	1.25	0.32	1.24	0.32	1.23	0.32
August	0.97	0.26	0.96	0.26	0.96	0.26
September	0.62	0.18	0.61	0.18	0.61	0.18 +
October	0.73	0.19	0.74	0.19	0.74	0.19
November	1.03	0.25	1.03	0.25	1.03	0.25
December (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Subsequent Pregnancy and Birth						
Not Pregnant at 365 days (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Pregnant at 365 days	3.13	0.59 ***	3.29	0.62 ***	3.28	0.62 ***
No Subsequent Birth at 365 days (RC)	1.00	(--)	1.00	(--)	1.00	(--)

Subsequent Birth at 365 days	0.91	0.93	0.88	0.90	0.90	0.92
Breastfeeding						
Breastfeeding in days until day 165			.996	0.001 **	.996	0.001 **
Breastfeeding unknown			4.46	1.12 ***	4.25	1.08 ***
Immunizations						
No Measles shot at 365 days (RC)					1.00	(--)
Measles shot at 365 days					0.95	0.13
No Diphtheria shot at 365 days (RC)					1.00	(--)
Diphtheria shot at 365 days					0.83	0.15

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 4d. Results of Cox Proportional Hazards Model of Mortality (n=49,712) between 1.5 and 5 years in the MCH-FP Area with and without Controls for Breastfeeding and Immunizations

	RR	Std. Err.	RR	Std. Err.	RR	Std. Err.
First Birth	0.94	0.12	0.94	0.12	0.92	0.12
Inter-outcome Interval Duration						
IOI<15 months	1.03	0.26	1.03	0.26	1.01	0.26
IOI: 15-17 months	1.02	0.28	1.02	0.28	1.02	0.28
IOI: 18-23 months	1.01	0.18	1.01	0.18	1.01	0.18
IOI: 24-35 months	1.11	0.13	1.11	0.13	1.12	0.13
IOI: 36-59 months (RC)	1.00	(--)	1.00	(--)	1.00	(--)
IOI: 60-83 months	0.61	0.13 *	0.61	0.13 *	0.61	0.13 *
IOI: 84 plus months	0.97	0.28	0.96	0.28	0.94	0.27
IOI unknown	1.26	0.15 +	1.25	0.15 +	1.17	0.15
Preceding Pregnancy Outcome						
Preceding Outcome Live Birth (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Preceding Outcome Abortion	0.00	0.00	0.00	0.00	0.00	0.00
Preceding Outcome Miscarriage	0.77	0.26	0.77	0.26	0.77	0.26
Preceding Outcome Stillbirth	0.89	0.35	0.89	0.35	0.89	0.35
Inter-outcome Interval * Non-live Preg. Outcome						
Interaction: IOI<15 months * Prec. outcome abortion	0.83	.	0.82	.	0.84	.
Interaction: IOI<15 months * Prec. outcome miscarriage	0.77	0.40	0.76	0.39	0.77	0.40
Interaction: IOI<15 months * Prec. outcome stillbirth	1.11	0.65	1.11	0.65	1.10	0.65
Duration of Pregnancy Gestation						
Gestation <30 weeks	0.88	0.15	0.89	0.15	0.89	0.15
Gestation 30-31 weeks	0.86	0.13	0.86	0.13	0.86	0.13
Gestation 32-33 weeks	0.98	0.11	0.98	0.11	0.98	0.11
Gestation 34-35 weeks	0.86	0.08	0.86	0.08	0.86	0.08
Gestation 36-37 weeks (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Gestation 38-39 weeks	0.77	0.09 *	0.77	0.09 *	0.77	0.09 *
Gestation 40 plus weeks	1.02	0.14	1.03	0.14	1.02	0.14
Gestation unknown	1.18	0.20	0.83	0.16	0.80	0.16
Wantedness Status						
Not Wanted	1.01	0.27	1.01	0.27	1.01	0.27
Wanted (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Wantedness unknown	0.88	0.13	0.86	0.12	0.87	0.12
Birth Parity						
Parity 2-3 (RC)	1.00	(--)	1.00	(--)		
Parity 4-7	1.38	0.14 **	1.38	0.14 **	1.37	0.14 **
Parity 8 plus	1.86	0.36 **	1.84	0.36 **	1.79	0.35 **
Maternal Education						
Mother's Ed: 0 years (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Mother's Ed: 1-5 years	0.76	0.07 **	0.76	0.07 **	0.76	0.07 **
Mother's Ed: 6-10 years	0.64	0.09 **	0.63	0.09 **	0.64	0.09 **
Mother's Ed: 11-16 years	0.43	0.20 +	0.42	0.19 +	0.42	0.19 +
Mother's Ed unknown	0.87	0.18	0.87	0.18	0.88	0.18

Father's Education						
Father's Ed: 0 years (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Father's Ed: 1-5 years	0.99	0.11	0.98	0.11	0.99	0.11
Father's Ed: 6-10 years	0.98	0.13	0.97	0.13	0.98	0.13
Father's Ed: 11-16 years	0.92	0.20	0.92	0.20	0.93	0.20
Father's Ed unknown	1.16	0.13	1.15	0.13	1.15	0.13
Maternal Age						
Mother's Age <18	1.26	0.32	1.27	0.32	1.22	0.31
Mother's Age: 18-19	1.00	0.17	0.99	0.17	0.97	0.17
Mother's Age: 20-24	1.08	0.11	1.08	0.11	1.07	0.11
Mother's Age: 25-29 (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Mother's Age: 30-34	1.00	0.11	1.00	0.11	1.00	0.11
Mother's Age: 35 plus	0.83	0.13	0.83	0.13	0.85	0.13
Gender						
Female	1.38	0.10***	1.38	0.10***	1.38	0.10***
Male (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Religion						
Non-Muslim	0.65	0.08***	0.65	0.08***	0.65	0.08***
Muslim (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Household Space Size						
House Size Smallest Quartile (RC)	1.00	(--)	1.00	(--)	1.00	(--)
House Size 2nd Quartile	0.90	0.08	0.91	0.08	0.91	0.08
House Size 3rd Quartile	0.85	0.08+	0.85	0.08+	0.85	0.08+
House Size Largest Quartile	0.91	0.11	0.92	0.11	0.92	0.11
House Size unknown	0.72	0.19	0.70	0.18	0.70	0.18
Year						
Year 1982-1986 (RC)						
Year 1987-1991	0.66	0.06***	0.65	0.06***	0.71	0.08**
Year 1992-1996	0.53	0.08***	0.52	0.08***	0.57	0.09***
Year 1997-1999	0.44	0.08***	0.43	0.08***	0.48	0.09***
Year 2000-2002	0.32	0.12**	0.32	0.11**	0.36	0.13**
Month of Birth						
January	1.11	0.16	1.11	0.16	1.10	0.16
February	0.75	0.13	0.75	0.13+	0.74	0.13+
March	1.00	0.16	1.00	0.16	1.00	0.16
April	0.61	0.12*	0.62	0.12*	0.61	0.12*
May	1.06	0.17	1.06	0.17	1.06	0.17
June	0.76	0.14	0.76	0.14	0.75	0.14
July	0.97	0.16	0.98	0.16	0.97	0.16
August	1.13	0.17	1.13	0.17	1.13	0.17
September	1.03	0.15	1.02	0.15	1.02	0.15
October	0.82	0.12	0.83	0.12	0.82	0.12
November	0.85	0.12	0.85	0.12	0.85	0.12
December (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Subsequent Pregnancy and Birth						
Not Pregnant at 548 days (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Pregnant at 548 days	2.13	0.20***	2.15	0.20***	2.13	0.20***
No Subsequent Birth at 548 days (RC)	1.00	(--)	1.00	(--)	1.00	(--)

Subsequent Birth at 548 days	0.85	0.21	0.90	0.22	0.92	0.23
Breastfeeding						
Breastfeeding in days until day 493			1.00	0.00	1.00	0.00
Breastfeeding unknown			2.96	0.67 ***	2.74	0.63 ***
Immunizations						
No Measles shot at 548 days (RC)					1.00	(--)
Measles shot at 548 days					0.92	0.10
No Diphtheria shot at 548 days (RC)					1.00	(--)
Diphtheria shot at 548 days					0.84	0.10

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 5. Results of Polytomous Logistic Regression for Pregnancy Outcome where Live Birth is the Reference Category (n=65,378)

	Abortion		Miscarriage		Stillbirth	
	exp(ß)	Std. Err.	exp(ß)	Std. Err.	exp(ß)	Std. Err.
First Birth	4.77	0.10 ***	9.75	0.06 ***	11.06	0.08 ***
Interpregnancy Interval Duration						
IPI<6 months	10.03	0.11 ***	5.81	0.09 ***	2.32	0.13 ***
IPI: 6-8 months	3.89	0.21 ***	3.22	0.14 ***	2.43	0.18 ***
IPI: 9-14 months	3.02	0.14 ***	2.37	0.10 ***	2.28	0.13 ***
IPI: 15-26 months	1.97	0.11 ***	2.15	0.07 ***	1.98	0.09 ***
IPI: 27-50 months (RC)	1.00	(--)	1.00	(--)	1.00	(--)
IPI: 51-74 months	1.33	0.12 *	1.64	0.08 ***	1.30	0.11 *
IPI: 75 plus months	1.74	0.12 ***	1.64	0.10 ***	1.53	0.14 **
IPI unknown	1.63	0.11 ***	1.43	0.08 ***	1.42	0.10 **
Wantedness Status						
Not Wanted	3.95	0.10 ***	1.56	0.11 ***	1.06	0.17
Wanted (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Wanted unknown	0.92	0.09	0.66	0.06 ***	0.76	0.07 ***
Birth Parity						
Parity 2-3 (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Parity 4-7	0.57	0.08 ***	0.35	0.06 ***	0.39	0.08 ***
Parity 8 plus	0.31	0.15 ***	0.22	0.13 ***	0.27	0.16 ***
Maternal Education						
Mother's Ed: 0 years (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Mother's Ed: 1-5 years	1.19	0.07 *	0.94	0.04	0.89	0.06 +
Mother's Ed: 6-10 years	1.60	0.08 ***	0.80	0.06 ***	0.71	0.08 ***
Mother's Ed: 11-16 years	1.00	0.18	0.56	0.12 ***	0.39	0.18 ***
Mother's Ed unknown	0.55	0.31 +	0.64	0.14 **	0.80	0.17
Father's Education						
Father's Ed: 0 years (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Father's Ed: 1-5 years	1.16	0.08 +	0.97	0.05	1.12	0.07 +
Father's Ed: 6-10 years	1.29	0.09 **	1.05	0.06	1.15	0.08 +
Father's Ed: 11-16 years	1.14	0.13	1.08	0.09	0.92	0.13
Father's Ed unknown	1.02	0.09	0.92	0.06	0.99	0.07
Maternal Age						
Mother's Age <18	0.84	0.17	0.41	0.10 ***	0.17	0.18 ***
Mother's Age: 18-19	0.37	0.15 ***	0.30	0.08 ***	0.24	0.10 ***
Mother's Age: 20-24	0.41	0.10 ***	0.35	0.05 ***	0.36	0.07 ***
Mother's Age: 25-29 (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Mother's Age: 30-34	2.97	0.09 ***	1.79	0.06 ***	2.29	0.08 ***
Mother's Age: 35 plus	8.74	0.10 ***	4.55	0.08 ***	4.68	0.10 ***
Religion						
Non-Muslim	1.35	0.08 ***	0.91	0.05 +	1.09	0.07
Muslim (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Household Space Size						
House Size Smallest Quartile (RC)	1.00	(--)	1.00	(--)	1.00	(--)

House Size 2nd Quartile	1.21	0.08 *	1.00	0.05	0.94	0.07
House Size 3rd Quartile	1.27	0.08 **	0.97	0.05	0.95	0.06
House Size Largest Quartile	1.53	0.09 ***	0.94	0.06	0.85	0.08 +
House Size unknown	1.66	0.14 ***	0.91	0.05 +	1.05	0.13
Preceding Pregnancy Outcome						
Preceding Outcome Live Birth (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Preceding Outcome Abortion	1.86	0.15 ***	0.48	0.20 ***	1.12	0.22
Preceding Outcome Miscarriage	0.11	0.21 ***	0.45	0.10 ***	0.57	0.14 ***
Preceding Outcome Stillbirth	0.21	0.23 ***	0.44	0.12 ***	1.10	0.13
Year						
Year 1982-1986 (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Year 1987-1991	1.41	0.09 ***	0.88	0.06 *	0.84	0.07 *
Year 1992-1996	0.91	0.12	0.56	0.07 ***	0.57	0.09 ***
Year 1997-1999	0.85	0.13	0.49	0.08 ***	0.48	0.10 ***
Year 2000-2002	1.15	0.12	0.70	0.07 ***	0.53	0.10 ***
Month of Outcome						
January	1.21	0.16	1.39	0.10 **	1.01	0.11
February	1.73	0.15 ***	1.63	0.10 ***	0.89	0.12
March	2.65	0.14 ***	2.08	0.10 ***	1.05	0.11
April	2.65	0.14 ***	2.54	0.09 ***	1.05	0.12
May	2.54	0.14 ***	2.91	0.09 ***	0.99	0.12
June	2.89	0.14 ***	3.13	0.09 ***	0.78	0.13 +
July	2.20	0.14 ***	2.66	0.09 ***	0.87	0.12
August	1.74	0.15 ***	2.05	0.09 ***	0.96	0.11
September	1.52	0.14 **	1.68	0.09 ***	1.03	0.10
October	1.18	0.15	1.37	0.09 **	0.99	0.10
November	0.90	0.15	1.15	0.10	1.05	0.10
December (RC)	1.00	(--)	1.00	(--)	1.00	(--)
Constant	0.003	0.20 ***	0.03	0.12 ***	0.03	0.14 ***

+ p<.10, * p<.05, ** p<.01, *** p<.001
note: exp(ß) = odds ratio

Appendix Table 6. OLS Regressions on Pregnancy Duration in Weeks by Types of Pregnancy Outcomes

	Stillbirth and Livebirths Only (n=57,759)		Miscarriages Only (n=2,623)		Abortions Only (n=945)	
	ß	Std. Err.	ß	Std. Err.	ß	Std. Err.
First Birth	0.02	0.04	-0.17	0.23	1.05	0.38 **
Interpregnancy Interval Duration						
IPI<6 months	-0.31	0.07 ***	-0.22	0.37	-0.19	0.45
IPI: 6-8 months	-0.27	0.10 *	-0.33	0.53	-0.03	0.63
IPI: 9-14 months	-0.04	0.07	0.65	0.38 +	-0.86	0.40 *
IPI: 15-26 months	-0.07	0.04	-0.24	0.24	-0.53	0.29 +
IPI: 27-50 months (RC)						
IPI: 51-74 months	-0.02	0.05	0.00	0.28	-0.03	0.33
IPI: 75 plus months	-0.22	0.07 **	-0.08	0.34	-0.31	0.34
IPI unknown	0.29	0.05 ***	0.05	0.32	-0.52	0.39
Wantedness Status						
Not Wanted	-0.09	0.08	0.69	0.40 +	-0.58	0.30 +
Wanted (RC)						
Wanted unknown	-0.12	0.04 **	-0.12	0.21	-0.72	0.31 *
Birth Parity						
Parity 2-3 (RC)						
Parity 4-7	-0.18	0.04 ***	-0.52	0.26 *	0.40	0.27
Parity 8 plus	-0.43	0.08 ***	-0.07	0.50	1.32	0.49 **
Maternal Education						
Mother's Ed: 0 years (RC)						
Mother's Ed: 1-5 years	0.08	0.03 *	0.10	0.17	-0.19	0.24
Mother's Ed: 6-10 years	0.26	0.04 ***	-0.36	0.22	-0.13	0.29
Mother's Ed: 11-16 years	0.61	0.09 ***	-0.65	0.46	-2.31	0.58 ***
Mother's Ed unknown	0.12	0.09	0.20	0.68	-0.56	1.21
Father's Education						
Father's Ed: 0 years (RC)						
Father's Ed: 1-5 years	0.01	0.04	-0.32	0.20	0.29	0.27
Father's Ed: 6-10 years	0.02	0.04	0.09	0.23	0.02	0.29
Father's Ed: 11-16 years	0.07	0.06	0.08	0.33	0.19	0.42
Father's Ed unknown	0.04	0.04	0.00	0.24	0.13	0.37
Maternal Age						
Mother's Age <18	-0.16	0.09 +	0.19	0.40	-1.17	0.72
Mother's Age: 18-19	-0.09	0.06	0.54	0.31 +	-0.74	0.64
Mother's Age: 20-24	-0.01	0.04	-0.02	0.21	0.23	0.39
Mother's Age: 25-29 (RC)						
Mother's Age: 30-34	-0.09	0.04 *	-0.42	0.25 +	-0.36	0.31
Mother's Age: 35 plus	-0.33	0.06 ***	-0.60	0.30 *	-0.12	0.35
Religion						
Non-Muslim	1.35	0.08 ***	0.18	0.21	-0.38	0.26
Muslim (RC)						
Household Space Size						
House Size Smallest Quartile (RC)						

House Size 2nd Quartile	0.00	0.03	-0.26	0.20	-0.14	0.30
House Size 3rd Quartile	0.02	0.03	-0.15	0.20	-0.28	0.29
House Size Largest Quartile	-0.02	0.04	0.29	0.25	-0.49	0.33
House Size unknown	-0.04	0.07	-0.28	0.39	-0.46	0.50
Preceding Pregnancy Outcome						
Preceding Outcome Live Birth (RC)						
Preceding Outcome Abortion	0.09	0.14	0.49	0.76	-0.53	0.43
Preceding Outcome Miscarriage	0.14	0.08 +	0.00	0.36	-0.74	0.74
Preceding Outcome Stillbirth	0.10	0.09	0.17	0.46	-0.02	0.79
Year						
Year 1982-1986 (RC)						
Year 1987-1991	-1.82	0.05 ***	-2.08	0.29 ***	-0.82	0.46 +
Year 1992-1996	-0.80	0.05 ***	-0.35	0.25	0.52	0.34
Year 1997-1999	-0.41	0.04 ***	-0.16	0.23	0.79	0.30 **
Year 2000-2002	-0.20	0.05 ***	-0.06	0.25	0.68	0.32 *
Month of Outcome						
January	0.01	0.06	-0.57	0.41	-0.13	0.53
February	0.13	0.06 *	-0.38	0.40	0.17	0.51
March	-0.01	0.06	-1.00	0.38 *	0.15	0.46
April	0.01	0.06	-1.04	0.37 **	-0.19	0.47
May	0.00	0.06	-0.61	0.37 +	0.38	0.48
June	-0.16	0.06 *	-0.03	0.37	0.44	0.47
July	-0.22	0.06 ***	0.06	0.37	0.74	0.49
August	-0.43	0.06 ***	0.19	0.37	0.39	0.49
September	-0.27	0.05 ***	-0.74	0.39 +	0.16	0.50
October	-0.27	0.05 ***	-0.49	0.38	0.04	0.53
November	-0.21	0.05 ***	-0.28	0.39	-0.67	0.53
December (RC)						
Constant	36.46	0.07 ***	10.53	0.42 ***	7.16	0.58 ***

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 7a. Results of Cox proportional hazards model of first-week mortality: Effects of MCH-FP area with and without controls for reproductive variables (n=125,720)

	RR	Std. Err.	RR	Std. Err.
Area				
Comparison Area (RC)	1.00	(--)	1.00	(--)
MCH-FP Area	0.84	0.03 ***	1.03	0.09
Interaction: Gestation unknown* MCHFP			1.08	0.24
Inter-outcome Interval Duration				
IOI<15 months			3.01	0.24 ***
IOI: 15-17 months			1.29	0.15 *
IOI: 18-23 months			1.15	0.09 +
IOI: 24-35 months			0.89	0.06 +
IOI: 36-59 months (RC)			1.00	(--)
IOI: 60-83 months			1.07	0.10
IOI: 84 plus months			1.17	0.15
IOI unknown			1.11	0.07
Preceding Pregnancy Outcome				
Preceding Outcome Live Birth (RC)			1.00	(--)
Preceding Outcome Abortion			0.75	0.17
Preceding Outcome Miscarriage			1.18	0.15
Preceding Outcome Stillbirth			1.18	0.18
Inter-outcome Interval * Non-live Prec. Outcome				
Interaction: IOI<15 months * Prec. outcome abortion			0.38	0.14 **
Interaction: IOI<15 months * Prec. outcome miscarriage			0.35	0.06 ***
Interaction: IOI<15 months * Prec. outcome stillbirth			0.44	0.10 ***
Duration of Pregnancy Gestation				
Gestation <30 weeks			8.67	0.75 ***
Gestation 30-31 weeks			4.54	0.41 ***
Gestation 32-33 weeks			2.53	0.22 ***
Gestation 34-35 weeks			1.46	0.13 ***
Gestation 36-37 weeks (RC)			1.00	(--)
Gestation 38-39 weeks			1.10	0.11
Gestation 40 plus weeks			1.64	0.19 ***
Gestation unknown			2.64	0.29 ***
Birth Parity				
First Birth			1.80	0.11 ***
Parity 2-3 (RC)			1.00	(--)
Parity 4-7			1.04	0.06
Parity 8 plus			1.36	0.14 **
Maternal Age				
Mother's Age <18			1.68	0.13 ***
Mother's Age: 18-19			1.31	0.07 ***
Mother's Age: 20-24 (RC)			1.00	(--)
Mother's Age: 25-29			0.95	0.05

Mother's Age: 30-34	1.00	0.07
Mother's Age: 35 plus	1.04	0.09
Year		
Year 1982-1986	0.87	0.07 +
Year 1987-1991	0.90	0.07
Year 1992-1996	0.95	0.07
Year 1997-1999	0.82	0.07 *
Year 2000-2002 (RC)	1.00	(--)

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 7b. Results of Cox proportional hazards model of late neonatal mortality: Effects of MCH-FP area with and without controls for reproductive variables (n=121,936)

	RR	Std. Err.	RR	Std. Err.
Area				
Comparison Area (RC)	1.00	(--)	1.00	(--)
MCH-FP Area	0.63	0.03 ***	0.98	0.16
Interaction: Gestation unknown* MCHFP			2.02	0.25 ***
Inter-outcome Interval Duration				
IOI<15 months			2.22	0.29 ***
IOI: 15-17 months			1.39	0.23 +
IOI: 18-23 months			1.24	0.14 +
IOI: 24-35 months			1.18	0.10 +
IOI: 36-59 months (RC)			1.00	(--)
IOI: 60-83 months			0.87	0.15
IOI: 84 plus months			1.17	0.26
IOI unknown			1.09	0.10
Preceding Pregnancy Outcome				
Preceding Outcome Live Birth (RC)			1.00	(--)
Preceding Outcome Abortion			1.21	0.32
Preceding Outcome Miscarriage			0.65	0.15 +
Preceding Outcome Stillbirth			0.95	0.23
Inter-outcome Interval * Non-live Prec. Outcome				
Interaction: IOI<15 months * Prec. outcome abortion			0.48	0.21 +
Interaction: IOI<15 months * Prec. outcome miscarriage			0.71	0.22
Interaction: IOI<15 months * Prec. outcome stillbirth			0.37	0.14 *
Duration of Pregnancy Gestation				
Gestation <30 weeks			4.50	0.66 ***
Gestation 30-31 weeks			3.34	0.47 ***
Gestation 32-33 weeks			2.34	0.30 ***
Gestation 34-35 weeks			1.65	0.20 ***
Gestation 36-37 weeks (RC)			1.00	(--)
Gestation 38-39 weeks			0.92	0.14
Gestation 40 plus weeks			1.00	0.21
Gestation unknown			2.66	0.50 ***
Birth Parity				
First Birth			1.66	0.15 ***
Parity 2-3 (RC)			1.00	(--)
Parity 4-7			1.04	0.06
Parity 8 plus			1.36	0.14 **
Maternal Age				
Mother's Age <18			1.70	0.19 ***
Mother's Age: 18-19			1.13	0.10
Mother's Age: 20-24 (RC)			1.00	(--)
Mother's Age: 25-29			0.77	0.06 ***

Mother's Age: 30-34	0.95	0.09
Mother's Age: 35 plus	0.86	0.11
Year		
Year 1982-1986	1.78	0.24***
Year 1987-1991	1.51	0.20**
Year 1992-1996	1.09	0.15
Year 1997-1999	0.81	0.12
Year 2000-2002 (RC)	1.00	(--)

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 7c. Results of Cox proportional hazards model of post-neonatal mortality: Effects of MCH-FP area with and without controls for reproductive variables (n=119,718)

	RR	Std. Err.	RR	Std. Err.
Area				
Comparison Area (RC)	1.00	(--)	1.00	(--)
MCH-FP Area	0.80	0.03 ***	1.10	0.14
Interaction: Gestation unknown* MCHFP			1.21	0.20
Inter-outcome Interval Duration				
IOI<15 months			1.80	0.18 ***
IOI: 15-17 months			1.72	0.18 ***
IOI: 18-23 months			1.51	0.11 ***
IOI: 24-35 months			1.04	0.06
IOI: 36-59 months (RC)			1.00	(--)
IOI: 60-83 months			0.81	0.09 *
IOI: 84 plus months			1.23	0.17
IOI unknown			1.11	0.07 +
Preceding Pregnancy Outcome				
Preceding Outcome Live Birth (RC)			1.00	(--)
Preceding Outcome Abortion			0.46	0.12 **
Preceding Outcome Miscarriage			0.70	0.10 *
Preceding Outcome Stillbirth			0.98	0.15
Inter-outcome Interval * Non-live Prec. Outcome				
Interaction: IOI<15 months * Prec. outcome abortion			1.12	0.44
Interaction: IOI<15 months * Prec. outcome miscarriage			0.75	0.15
Interaction: IOI<15 months * Prec. outcome stillbirth			0.75	0.17
Duration of Pregnancy Gestation				
Gestation <30 weeks			1.96	0.21 ***
Gestation 30-31 weeks			1.88	0.17 ***
Gestation 32-33 weeks			1.53	0.12 ***
Gestation 34-35 weeks			1.02	0.08
Gestation 36-37 weeks (RC)			1.00	(--)
Gestation 38-39 weeks			0.97	0.08
Gestation 40 plus weeks			1.02	0.12
Gestation unknown			1.62	0.22 ***
Birth Parity				
First Birth			1.53	0.09 ***
Parity 2-3 (RC)			1.00	(--)
Parity 4-7			1.11	0.06 *
Parity 8 plus			1.57	0.14 ***
Maternal Age				
Mother's Age <18			1.28	0.12 *
Mother's Age: 18-19			1.03	0.07
Mother's Age: 20-24 (RC)			1.00	(--)
Mother's Age: 25-29			0.92	0.05 +
Mother's Age: 30-34			1.04	0.07

Mother's Age: 35 plus	1.16	0.10 +
Year		
Year 1982-1986	2.34	0.23 ***
Year 1987-1991	2.03	0.20 ***
Year 1992-1996	1.51	0.15 ***
Year 1997-1999	1.19	0.13 +
Year 2000-2002 (RC)	1.00	(--)

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix Table 7d. Results of Cox proportional hazards model of child mortality: Effects of MCH-FP area with and without controls for reproductive variables (n=110,191)

	RR	Std. Err.	RR	Std. Err.
Area				
Comparison Area (RC)	1.00	(--)	1.00	(--)
MCH-FP Area	0.64	0.02 ***	0.81	0.14
Interaction: Gestation unknown* MCHFP			1.18	0.25
Inter-outcome Interval Duration				
IOI<15 months			1.11	0.13
IOI: 15-17 months			1.11	0.15
IOI: 18-23 months			1.31	0.10 ***
IOI: 24-35 months			1.22	0.07 **
IOI: 36-59 months (RC)			1.00	(--)
IOI: 60-83 months			0.79	0.09 +
IOI: 84 plus months			1.00	0.17
IOI unknown			1.36	0.09 ***
Preceding Pregnancy Outcome				
Preceding Outcome Live Birth (RC)			1.00	(--)
Preceding Outcome Abortion			0.41	0.14 **
Preceding Outcome Miscarriage			0.72	0.12 *
Preceding Outcome Stillbirth			0.95	0.18
Inter-outcome Interval * Non-live Prec. Outcome				
Interaction: IOI<15 months * Prec. outcome abortion			2.74	1.19 *
Interaction: IOI<15 months * Prec. outcome miscarriage			1.19	0.28
Interaction: IOI<15 months * Prec. outcome stillbirth			0.88	0.26
Duration of Pregnancy Gestation				
Gestation <30 weeks			0.91	0.13
Gestation 30-31 weeks			0.94	0.11
Gestation 32-33 weeks			1.08	0.10
Gestation 34-35 weeks			0.87	0.07 +
Gestation 36-37 weeks (RC)			1.00	(--)
Gestation 38-39 weeks			0.86	0.08
Gestation 40 plus weeks			1.06	0.12
Gestation unknown			1.16	0.21
Birth Parity				
First Birth			0.95	0.07
Parity 2-3 (RC)			1.00	(--)
Parity 4-7			1.32	0.07 ***
Parity 8 plus			1.70	0.15 ***
Maternal Age				
Mother's Age <18			1.13	0.15
Mother's Age: 18-19			1.06	0.08
Mother's Age: 20-24 (RC)			1.00	(--)
Mother's Age: 25-29			1.00	0.05

Mother's Age: 30-34	1.05	0.07
Mother's Age: 35 plus	0.87	0.07 +
Year		
Year 1982-1986	2.11	0.31 ***
Year 1987-1991	1.27	0.19
Year 1992-1996	1.06	0.16
Year 1997-1999	0.83	0.13
Year 2000-2002 (RC)	1.00	(--)

+ p<.10, * p<.05, ** p<.01, *** p<.001

Appendix 8. How Do the Effects of Interval that We Find for Matlab Compare to Rutstein's Results for the Demographic and Health Surveys (DHS)

One of the analyses that is widely cited in the recent policy discussion of the Optimal Birthspacing Initiative is Shea Rutstein's analysis of data from the Demographic and Health Surveys (DHS) (e.g., Rutstein, 2003). The DHS project has fielded surveys that collect comparable data in a large number of countries. The core DHS questionnaire includes a birth history that collects retrospective information on all woman's births and the survival status of each. Such data can be used to construct indicators of mortality and of interbirth intervals. The surveys also collect data on a number of covariates of infant and child mortality. The DHS data have been widely used for studies of infant and child mortality.

We investigate how the effects of preceding intervals on infant and child mortality in Matlab compare to those in Rutstein (2003b), a study that pools data from DHS surveys in 17 countries, including Bangladesh. To do this, we re-analyze our data using the same types of samples, dependent variables, measures of interbirth intervals, and analytical methods that Rutstein used. The years in which the data he uses were collected range from as early as 1992-1993 for India to as recent as 1996-1997 for Bangladesh. He includes all births that occur within the 15 years prior to the survey.[35] He estimates a logistic regression to assess the effects of interbirth intervals of various durations on the outcomes of neonatal mortality, infant mortality, and under-5 child mortality. For all three outcomes, his sample, and ours for this comparative analysis, includes live births, and the outcome variable is death (death=1, no death=0) during the at-risk period considered (the first 28 days of life, the first year of life, and the first five years of life).[36] We restrict our samples to individuals who did not migrate out during the at-risk period[37] and were born far enough in advance of the end of the study period (December 31, 2002) to have been able to survive to the end of it.[38] In all, we consider 124,715, 115,102, and 84,753 singleton live births for our analyses of neonatal, infant, and under-five mortality, whereas Rutstein considers 278,443 live births.

[35] Because he uses retrospective data collected from women of childbearing age at the time of the survey, his data on earlier years will not include older women, whereas ours do. E.g., since the oldest women in his data at the time of the survey are age 49, the oldest women 15 years before the survey were age 34.

[36] Such an approach, where each "older" category includes the one before makes it difficult to assess whether and how the effects of birth interval change as the child becomes older.

[37] Due to out-migration before the end of the time period, we lose 537 records for our analysis of neonatal mortality, 5,341 for infant mortality, and 15,734 for under-five mortality.

[38] In restricting our sample to children born early enough that we have the opportunity to observe them over the entire at-risk period, we lose 568 births for neonatal mortality, 6,719 for infant mortality, and 30,586 for under-five mortality.

To replicate Rutstein's specification, we included categorical variables for the same categories of the length of the preceding interbirth interval that he considers (<18 months, 18-23 months, 24-29 months, 30-35 months, 36-41 months, 42-47 months, 48-53 months, 54-59 months, 60 or more months). In addition, like Rutstein, we control for the sex of the child, birth order (first birth, second or third birth, fourth through seventh birth, and eighth or higher birth), mother's age at birth (specified to have a linear effect), a dichotomous indicator of whether the preceding live birth survived until the birth of the index child, mother's education (Rutstein uses none, primary, secondary, and higher as the four categories; we use 0 years, 1-5 years, 6-10 years, and 11-16 years of education), an index of household wealth (he considers quintiles of wealth; we use our measure of household space), and an indicator of whether the child was wanted. Rutstein's measure of this last variable is retrospective and is only available for the births that occurred within five years preceding the survey, whereas ours is prospective. Rutstein only controls for wantedness in the regressions explaining neonatal and infant mortality because he only has the variable for the more recent births (those which have not lived to age 5), so we do this as well. Unlike Rutstein, we do not control for the type of provider of prenatal care, the timing of the prenatal care, the number of prenatal tetanus vaccinations, and whether the birth resulted from a contraceptive failure, though the last measure is not available for Rutstein in many of the countries where there is low contraceptive prevalence.[39] While Rutstein controls for rural and urban residence, we do not, since all of the women in our sample are from a rural area of Matlab.

In Appendix Figure 1, we portray the odds ratios of the risk of neonatal mortality (days 1-28) for each known interbirth interval considered relative to an interbirth interval of 36-41 months. We show the results from Rutstein's analysis (the triangles) and those based on our data (the squares). As in Preceding figures, hollow shapes indicate that the odds ratio is not significantly different from 1.0 at the 5% level. The general shapes of the relationships in our data are the same as Rutstein's. Specifically, the highest risk of neonatal mortality is associated with the shortest interbirth interval considered (<18 months) compared to intervals of 36-41 months in length. Rutstein's analysis finds that the risk associated with intervals of less than 18 months is 2.6 times the risk associated with an interval of 36-41 months, whereas we find a somewhat a smaller odds ratio, of 2.0. Neither Rutstein's nor our data show any sign of an increased risk of neonatal mortality for births after long intervals.

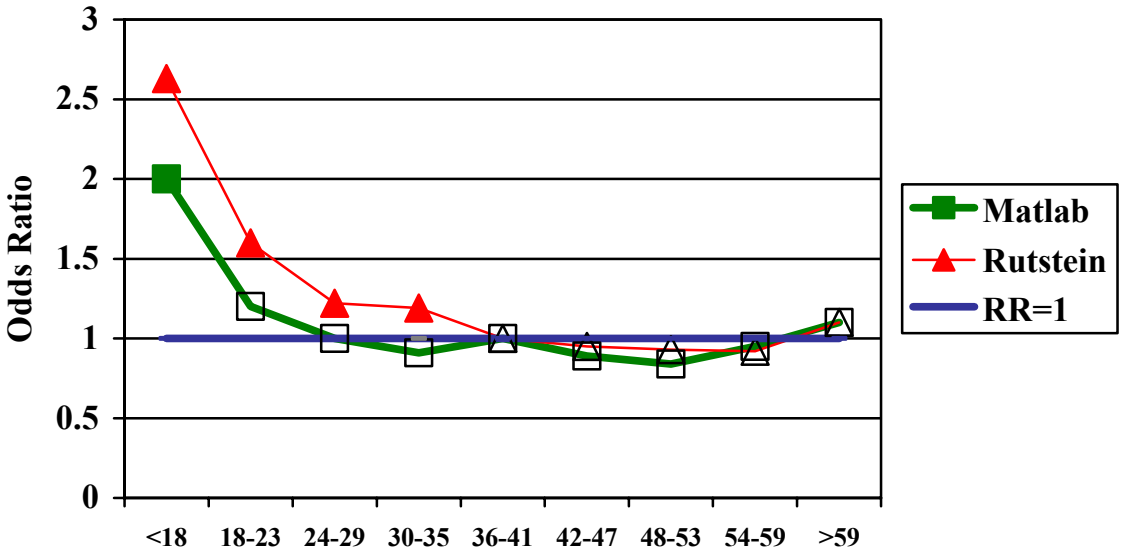
[39] We do not control for prenatal care because we only have that information for 2002; we do not have information on prenatal tetanus vaccinations or contraceptive failure.

In Appendix Figures 2 and 3, we present similar portrayals of the results of the logistic regression for infant mortality and under-five mortality, respectively. Again, we find a generally similar shape to Rutstein's analysis, indicating a higher infant mortality risk for pregnancies following intervals of less than 24 months than those for intervals of 36-41 months. For both infant and child mortality, like neonatal mortality, Rutstein's data show a higher odds ratio associated with short intervals relative to those of 36-41 months long than our data do. For example, Rutstein's data show an odds ratio of 2.9 associated with intervals of less than 18 months compared to one of 36-41 months, whereas our analyses imply an odds ratio of 1.9. Rutstein does not find statistically significant effects of long intervals on infant mortality, and neither do we. He finds that increasingly longer intervals are associated with significantly lower risks of child mortality, whereas we find no significant differences associated with increasing interval lengths beyond 23 months.

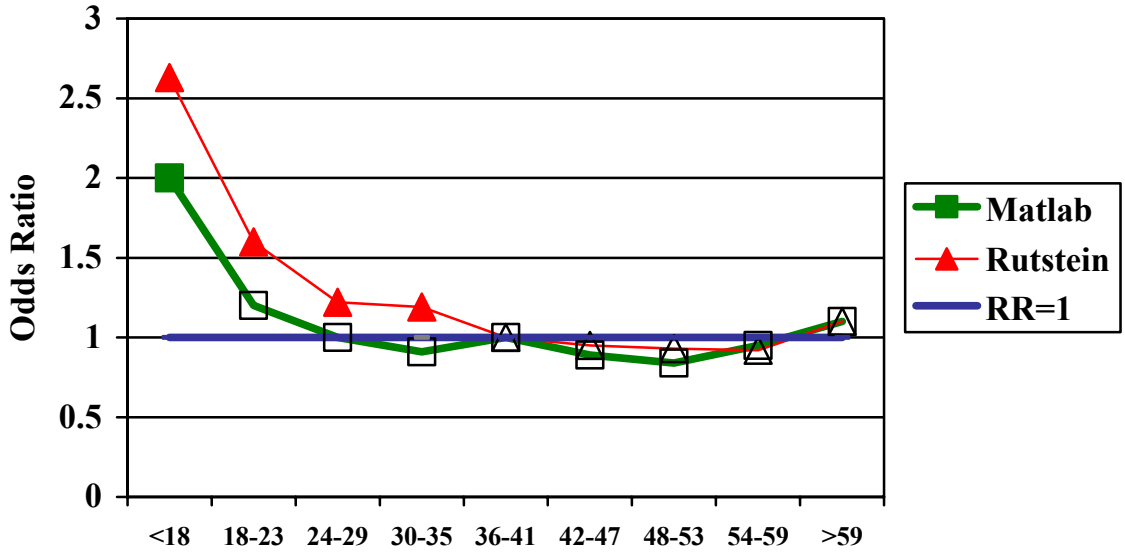
Hence, we see that even though our specifications are not identical to Rutstein's and our estimates of the effects of interbirth intervals are not exactly the same as his, the shapes of the relationships in the two studies are remarkably similar. The larger effect that he finds of very short intervals may reflect the possibility that his average short interval (< 18 mos.) is even shorter than ours because most of the countries he considers have lower levels of breastfeeding than Bangladesh.

The fact that he controls for some variables that we are not able to control (type of provider of prenatal care, the timing of the prenatal care, the number of prenatal tetanus vaccinations, and whether the birth resulted from a contraceptive failure) may also explain some of the difference between his results and ours, though we would expect that controlling for such variables would reduce rather than increase the deleterious effect of short intervals.

Appendix Figure 1 Effects of Interbirth Intervals on **Neonatal Mortality**: A comparison of Matlab data to Rutstein's data
(Hollow symbols indicate that relative risk is not different than 1.0 at a significance level of p<.05.)



Appendix Figure 2 Effects of Interbirth Intervals on **Infant Mortality**: A comparison of Matlab data to Rutstein's data
(Hollow symbols indicate that relative risk is not different than 1.0 at a significance level of p<.05.)



Appendix Figure 3 Effects of Interbirth Intervals on **Under-Five Mortality**: A comparison of Matlab data to Rutstein's data
(Hollow symbols indicate that relative risk is not different than 1.0 at a significance level of p<.05.)