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

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There is renewed programmatic interest in the effects of birth intervals on infant and child survival because family planning programs have the potential to affect birth spacing. For example, a Systematic Literature Review of the effects of birth intervals is being conducted, in consultation with USAID, WHO, and UNICEF, as part of the Optimal Birth Spacing Initiative. Understanding the size of these effects 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.

A number of analyses have examined the relationship between birth intervals and infant and child mortality, but few have adequately controlled for potentially confounding variables so that they can clearly understand the effect of varying birth intervals on child health and the reasons for these effects. 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. We also consider how the length of time since the last birth affects whether pregnancies result in a live birth (vs. a miscarriage, abortion, or stillbirth).

The relationship between short birth intervals and high infant and child mortality has been established in a wide range of populations (Miller et al., 1992; Miller, 1991; Winikoff, 1983; Millman and Cooksey, 1987). In addition, Rutstein (2000), in a cross-country analysis, shows that very long intervals (at least 5 years in length) are associated a slight increase in mortality. However, few studies have adequately controlled for potentially confounding factors such as prematurity, prior child death, breastfeeding, use of health services, gender composition of children, whether the birth was intended,

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household composition, health risks within the family, and socioeconomic factors. Controlling for these characteristics 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. This paper represents a first step toward this goal. We examine the effects of controlling for some of these factors. The others will be considered in our ongoing research.

This paper addresses the following research questions:

1) To what extent does the length of the previous birth interval affect pregnancy outcomes and the risks of infant, and child mortality?

2) Is the birth-interval effect U-shaped, i.e., are both too short and too long intervals pernicious to child survival? (and exactly what durations define too-short and too-long?)

3) At what age of child are the interval effects greatest? In particular, do the effects of the length of the preceding inter-birth interval differ across subperiods of infants and childhood?

4) Do the effect of inter-birth intervals remain when those of other potentially confounding variables (e.g., mother's age and education) are controlled?

5) How do the magnitudes of the mortality risks associated with "high-risk" birth intervals compare to those for other explanatory variables associated with a higher risk of mortality?

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

Why Birth Spacing Might Affect Pregnancy Outcomes and Infant and Child 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 birth interval for infant and child survival have centered on three *causal* mechanisms: 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); behavioral effects associated with competition between siblings or the inability (or lack of desire) to give a child adequate attention if his or her birth came sooner than desired; and disease transmission. 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. There are, however, reasons why there may *appear to be* a relationship between birthspacing and pregnancy and birth outcomes without the effect being causal. For 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 controlled may actually reflect these other factors. To our knowledge, there has been virtually no study of whether the amount of time since the last birth affects pregnancy outcomes (i.e., whether a pregnancy results in a live birth or ends with a miscarriage, abortion, or stillbirth).

Data

Our study uses data from the Matlab subdistrict of Bangladesh, where the Centre for Health and Population Research of the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B) has since 1966 been maintaining a Demographic Surveillance System (DSS) over a large population (220,000 people in 2002). The data contain information on a large number of pregnancies and births (145,839 pregnancies and 128,330 births between 1982 and 2002) and a sizable number of infant and child deaths (around 13,586 deaths before age 5).[1]

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.

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. Contraceptive use, antenatal care, child immunization,

[1] The data also include information on gestational age (for 1982-2002 for the MCH-FP area and for 1985-1998 for the comparison area; collected in the DSS Pregnancy Termination Form) and on the place where the child died (collected in the Death Form). We have not yet used these data in this project, but will soon.

and utilization of other child health services are all substantially higher 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 on pregnancy outcomes and on infant and child mortality differ between the two areas.

Another strength of the Matlab data for our analyses 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 3.4 in 2002, and the infant mortality rate declined from 100 infant deaths per 1,000 live births in the mid-1970s to 60 per 1,000 in 2002. During the same period, the child mortality rate (1-4 years) declined from 25 per 1,000 to 8 per 1,000, and the maternal mortality ratio declined from about 5 to 3.5 per 1,000 live births. 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, we have information on a number of socioeconomic and demographic variables that may affect birthspacing and/or mortality, e.g., age and education of the mother, household space (a proxy for the household's economic status), and religion. Furthermore, data are available on additional explanatory variables that we will consider in our subsequent work, including gestational age, contraceptive use, breastfeeding, whether the pregnancy was intended, and the immunization status of the mother and of children under the age of five. These may affect birth spacing and they may also pregnancy and birth outcomes; such a relationship could contribute to associations between birthspacing and these outcome measures.

Methods

Our analyses consider the following dependent variables:

- **pregnancy outcome**: whether a pregnancy ended with a miscarriage, abortion, stillbirth, or live birth. We consider a sample of 145,839 pregnancies that occurred between 1982 and 2002 and are documented in the DSS data.
- **early neonatal mortality**: whether a live-born child died in the first week of life. This analysis uses a sample of the 125,747 live singleton births reported in the DSS.
- **late neonatal mortality**: whether an infant who survived the first week of life (n = 122,001) died in the next three weeks.
- **post-neonatal mortality**: whether an infant who survived the first four weeks of life (n = 119,630) died before his or her first birthday.
- **child mortality**: whether children who survived until their first birthday (n =106,444) died before their fifth birthday.

Because multiple births have a considerably higher risk of morality, we exclude them (2,583 births in all) from our analyses of mortality. In our future research, we may also investigate the effects of birth intervals on the mortality of twins and triplets.

For each of these samples, we investigate the effects of six categories of birth intervals:

- less than 15 months between the previous live birth and the outcome of interest[2] (n=3,415)
- 15 months to 18 months (n=3,197)
- 19 months to 23 months (n=6,872)
- 24 months to 35 months (n=24,958)

[2] Each of our interval variables is measured as the amount of time between the previous live birth and the outcome of interest. For index outcomes that resulted in a live birth, this is the interval between the previous live birth and the index birth. For index outcomes that resulted in a non-live birth, this is the interval between the previous live birth and the miscarriage, abortion, or stillbirth. Such a measure includes the duration of the index pregnancy, which is problematic because this may itself affect the outcome of interest; e.g., babies born prematurely are more likely to die. In future work, we will consider the duration of the inter*pregnancy* interval; i.e., we will end our measurement of the interval with the time of the conception of the index pregnancy (and we will include the duration of that pregnancy as one of our covariates). In addition, we will measure this interval beginning at the time of the immediately preceding *pregnancy* outcome rather than the preceding live birth.

- 36 months to 83 months (n=36,696)[3]
- 84 or more months (n=4,576).

Because of our large number of observations, we have large sample sizes for each of the intervals we consider. This allows us to look at narrower distinctions and shorter birth intervals than previous researchers have. For example, Cleland and Sathar (1984), Rutstein (2003), and the 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 birth interval length.

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

For each of our dependent variables, we estimate an equation explaining the influences on it of the birth-interval and parity variables and also of other explanatory variables. For pregnancy outcome, these equations are estimated by polytomous logit, to explain how the explanatory variables affect the likelihood of a miscarriage, abortion, or stillbirth, relative to the likelihood of a live birth. (We also estimate a logistic regression that explains whether the outcome was a non-live birth [of any type] or a live birth.) For each of the dependent variables for 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).

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[3] We looked at all one-year intervals within this 3-7-year category, but the effects of these various subgroups never differed significantly from one another, so we have combined them.

We examine how the effects on each dependent variable differ across our various birth-interval categories and how these patterns vary across our various dependent variables. We also assess whether the birth-interval effects change when other covariates, which may be correlated with both the dependent variable and with birthspacing, are controlled. This enables us to see the extent to which the birth-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 birth intervals on a given dependent variable differ across subgroups. E.g., are the effects of birth 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 birth-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).

Results

Pregnancy Outcome

Figure 1 shows how the length of the preceding birth interval affects pregnancy outcomes. This, and the other figures that follow, are based on multivariate analyses that also control for birth parity, socioeconomic status (parental education and household space), religion, previous birth outcome, whether the woman lived in the MCH-FP area, and birth year. The full regressions are presented in tables in the Appendix. We see that very short birth intervals (<15 months) are associated with a very substantial increase in the risk of abortion and miscarriage. Specifically, the odds ratio that a pregnancy will end in abortion is 7.34 ($p<.001$) for a pregnancy with a preceding interval of less than 15 months relative to a pregnancy with a 3-7-year birth interval. The odds ratio of a pregnancy ending in miscarriage is 3.71 (p<.001) for a pregnancy with a less than 15-month birth interval relative to a 3-7-year birth interval. This effect remains large and significant for up to the 19-23-month birth-interval category. The effects of short birth intervals are not as large on stillbirths, but they are still significant. The risk of the pregnancy ending in stillbirth is 75.2% larger for those pregnancies preceded by a less than 15-month birth interval relative than those pregnancies that are preceded by a 3-7-year birth interval.

Figure 2 shows the results of a logistic regression for non-live birth outcomes (miscarriages, abortions, and stillbirths combined) with and without controls for other variables. Controlling for the other variables that we consider results in a *larger* effect of short birth intervals on the likelihood that a pregnancy results in a non-live birth outcome. Pregnancies associated with inter-birth intervals of less than 15 months are 4.17 times more likely to end in a non-live birth outcome than pregnancies with inter-birth intervals of three to seven years. The comparable number without controls is 2.68.

First-Week Mortality

Results of the Cox proportional hazards model for early neonatal mortality, seen in Figure 3, show that the relative risk of mortality during the first week varies by birth interval length, both with and without controls for other potentially confounding factors. The highest risk of mortality during this period is observed for pregnancies following the shortest birth interval. When the other explanatory variables that we consider are controlled, infants born after a previous birth interval of <15 months are 3.6 times more likely to die (p<.001) than those whose births were preceded by an inter-birth interval of three to seven years. The increased mortality risk remains present at a statistically significant level for both the 15-18-month and the 19-23-month previous birth intervals (54.3%, p<.001 and 27.5%, p<.01 respectively). An elevated risk of first-week mortality (33.9%, p<.01) is also observed for the births that occur 84 or more months after the previous birth relative to those pregnancies with inter-birth intervals of three to seven years. The comparable numbers without controls are somewhat higher for the intervals less than 24 months in length.

Late Neonatal Mortality

Figure 4 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. The effects become smaller when other variables are contolled. Even with these other variables controlled, however, the effect of short birth intervals remains statistically significant for all lengths of previous birth intervals shorter than 36 months (p<.001) relative to the birth intervals between three and seven years long. The highest risk is again observed at the shortest interval (<15 months). However, even for the babies born after an interval of 24-35 months there is a 34.8% increased risk of mortality during the late neonatal period relative to those pregnancies preceded by a three-to-seven-year interval between births. There is a somewhat elevated risk, of 26.5%, for the longest birth interval category, but it is not statistically significant.

Post-Neonatal Mortality

As shown in Figure 5, during the post-neonatal period, controlling for potentially confounding variables substantially reduces the magnitude of the birth interval effects. Even with the other variables controlled, however, post-neonatal mortality is higher after short birth intervals. In contrast to neonatal mortality, the highest mortality risk for post-neonatal mortality is for pregnancies that have a 15-18-month inter-birth interval, with an odds ratio of 2.10 (p<.001) relative to the reference category of a three-to-seven-year inter-birth interval. Babies born after an interval of two to three years experience a 17% (p<.01) increased risk of post-neonatal mortality relative to those born after a three-to-seven-year interval. The effect of a very long interval on post-neonatal mortality is not significantly different from that of intervals of three to seven years.

Child Mortality

As seen in Figure 6, the controls for the other variables explain all of the risk of high child mortality at the shortest inter-birth intervals that is seen when other covariates are not controlled. However, we still observe increased child mortality associated with intervals of 19-23 months and 24-35 months (40.4%, p<.001, and 28.9%, p<.01, respectively) relative to the birth intervals of three to seven years. There is a slight (but not statistically significant at p<.05) protective effect of very long birth intervals on child mortality.

Do the Effects of the Preceding Birth Interval Differ Among Population Subgroups?

We have explored whether the effects of birth interval lengths differ among population subgroups. The results are mixed. Statistically significant interactions were found for the non-live birth logistic regression when the birth intervals were interacted with residence in the MCH-FP area. At the very short inter-birth intervals, pregnancies in the MCH-FP area do not have quite as high a risk of ending a non-live birth as those in the comparison area (see Figure 7). This may reflect the fact that women in the MCH-FP area are better able to control the timing of their pregnancies. Closely-spaced births for them are probably more likely to be intended than those for women in the comparison area.

We failed to find sizeable and significant interactions between inter-birth intervals and other variables including year of birth, parity, and living in the MCH-FP area when analyzing influences on mortality.

Characteristics of Women by Birth Interval Length

The distribution of characteristics of women across the different intervals reveals that women with shorter previous birth intervals (<36 months) are more likely to be high parity (eight or more previous births) than those with longer intervals (Figure 8). Eight percent of the pregnancies with intervals shorter than 3 years were at parity of eight or greater as opposed to 5.1% of those with intervals longer than three years (p<.001). Pregnancies experienced after shorter intervals (less than 36 months) were more likely to be to younger women (Figure 9), women in the comparison area (Figure 10), and women who had the immediately preceding pregnancy end in live birth (rather than an induced abortion, miscarriage, or stillbirth) (Figure 11). The pregnancies preceded by intervals of less than 36-months are to women who are, on average, 27.6 years old, whereas those with longer intervals are, on average, two years older (29.7). Thirty-two percent of pregnancies preceded by intervals of less than 36 months occurred in the MCH-FP area, in contrast to 50.1 % of those pregnancies with birth intervals three years or longer ($p<.001$).

Long inter-birth intervals (84 months or more) are much more likely to include an intervening non-live birth (20.2%) than intervals of less than 36 months (3.0%) ($p<.001$).

Conclusions

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 that of women). Across all of the outcomes that we consider (whether the pregnancy ended in the non-live birth and mortality during four subperiods of infancy and childhood), the birth interval length that has the lowest risk a non-live birth and of infant and child mortality is three to seven years relative to all shorter intervals. Even for birth intervals of two to three years, there is an increased risk of late neonatal (34.8%), post-neonatal (17.1%), and child mortality (28.9%) relative to children born after intervals of three to seven years. Thus, the previously defined desired birth interval of at least two years could arguably be increased to at least three years.

The magnitudes of the mortality risks associated with “high-risk” birth intervals are large compared to those for other explanatory variables associated with a higher risk of mortality, especially for pregnancy outcomes and during the first month of life (see Figure 12). (We are not aware of other studies that have assessed the effects of the previous birth interval on pregnancy outcomes.) Pregnancies that follow intervals of less than 15 months are more than four times more likely to end in a non-live birth than those following an interval of three-to-seven years, and babies born after an interval of less than 15 months have an increased risk of mortality 3.6 times that of the lowest-risk group (three-to-seven-year inter-birth intervals). By contrast, mothers who are less than 16 years old have an increased risk of first-week mortality of 2.3 relative to the lowest-risk age category (22-30 year old women). In the post-neonatal period and childhood, the adverse effects of low socioeconomic status and no education have a larger magnitude than the effect of short birth intervals on mortality.

The mortality risks for very long intervals (seven years or longer) exist only during infancy. The reasons for this pattern are not well understood, but we do find that women with very long inter-birth intervals are more likely to have had their most recent previous pregnancy end in a non-live birth. The same factors that led to this higher incidence of non-live births may also lead to higher mortality risks for these women's children.

Plans for Future Work

We have just begun this project and haven't yet been able to explore many of the things that we plan to do. These include the following:

- **Investigating the sensitivity of conclusions about the effects of birth intervals to controlling for additional explanatory variables**, including breastfeeding, prematurity, immunizations, whether the pregnancy was intended, and gender composition of children.

- **Investigating the effect of cumulative short intervals**. Is the effect of a short interval 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.

- **A fixed-effects (or difference-in-difference) analysis where we will 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. Such an analysis enables us to net out the effects of unobserved factors (e.g., genetics) that are common to all of a woman's pregnancies.

- **Analyses like those we have done in this paper, and those just described, where maternal mortality and maternal morbidity are the outcomes of interest.** The DSS data document about 300 maternal deaths between 1982 and 2002.[4] Furthermore, since 1997 the Reproductive Health Unit of the Centre for Health and Population Research has been collecting data on maternal morbidity from about 2,500 women per year in the MCH-FP area of Matlab.[5]

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[4] The number of maternal deaths in our data is nearly 40% greater than the number that Conde-Agudelo and Belizán (2000) consider in their 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.

[5] Pregnant women have been given a pictoral card when their pregnancies are identified (by a community health worker during a regular household visit). The card depicts various problems that a woman might encounter during pregnancy. The woman keeps the card and brings it when visiting the

- **Consideration of the effects of inter*pregnancy* intervals** and how these differ from those of inter-birth intervals.

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heath centre. During each prenatal visit a wide range of information is collected, including weight, blood pressure, edema, proteinuria, glusosuria, anemia, hemorrhage, and leaking membranes. The women who are given the pictorial card are advised to visit a health clinic maintained by the ICDDR,B four times during their pregnancy to be examined by paramedic (though only 70% attended sub-centre and not all of these made all four visit); hence, a substantial portion of the health information has been verified by a medical professional. Although these data do not cover as long a period of time as the data on mortality discussed above and are not available for the comparison area and hence do not permit the comparisons between the MCH-PF and Comparison areas that will be possible in our analyses of maternal mortality, they nonetheless provide a unique opportunity to study the effects of pregnancy spacing on maternal morbidity in a low-income developing country.

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Figure 1. How length of preceding birth interval affects pregnancy outcome (with all controls). (Hollow symbols indicate that the odds ratio is not different than 1.0 at a significance level of p<.05.)

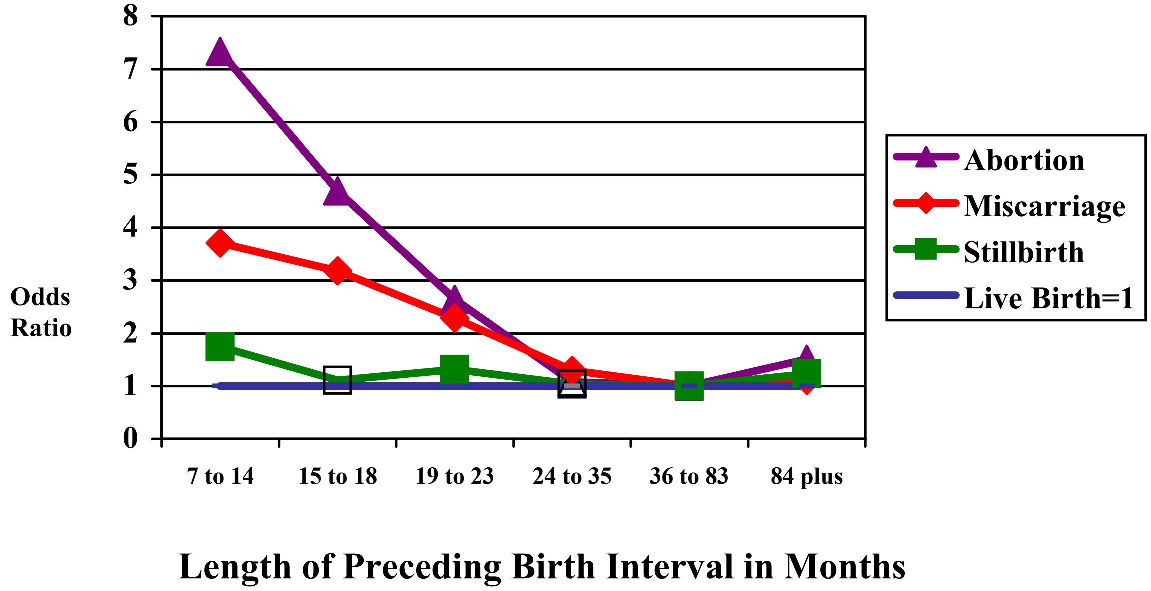

Figure 2. How length of preceding birth interval affects non-live birth outcomes, with and without controls for other variables. (Hollow symbols indicate that the odds ratio is not different than 1.0 at a significance level of p<.05.)

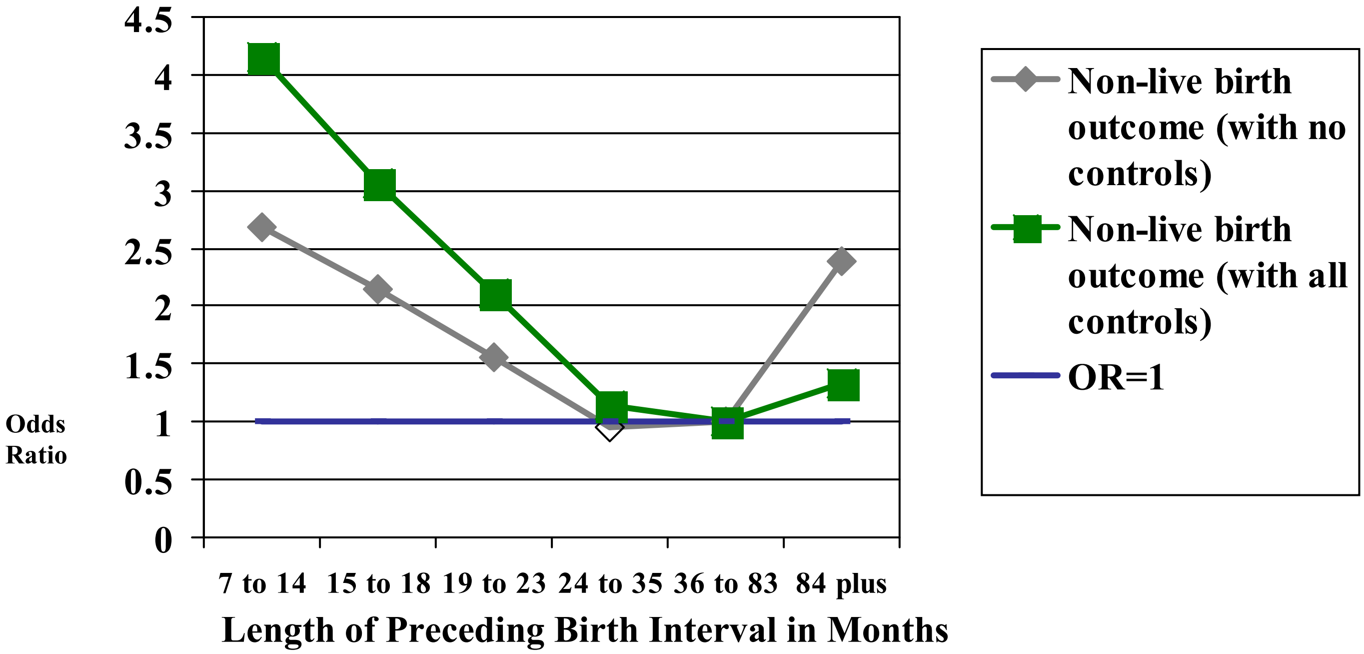

Figure 3. How length of preceding birth interval affects first-week mortality, with and without controls for other variables. (Hollow symbols indicate that the relative risk is not different than 1.0 at a significance level of p<.05.)

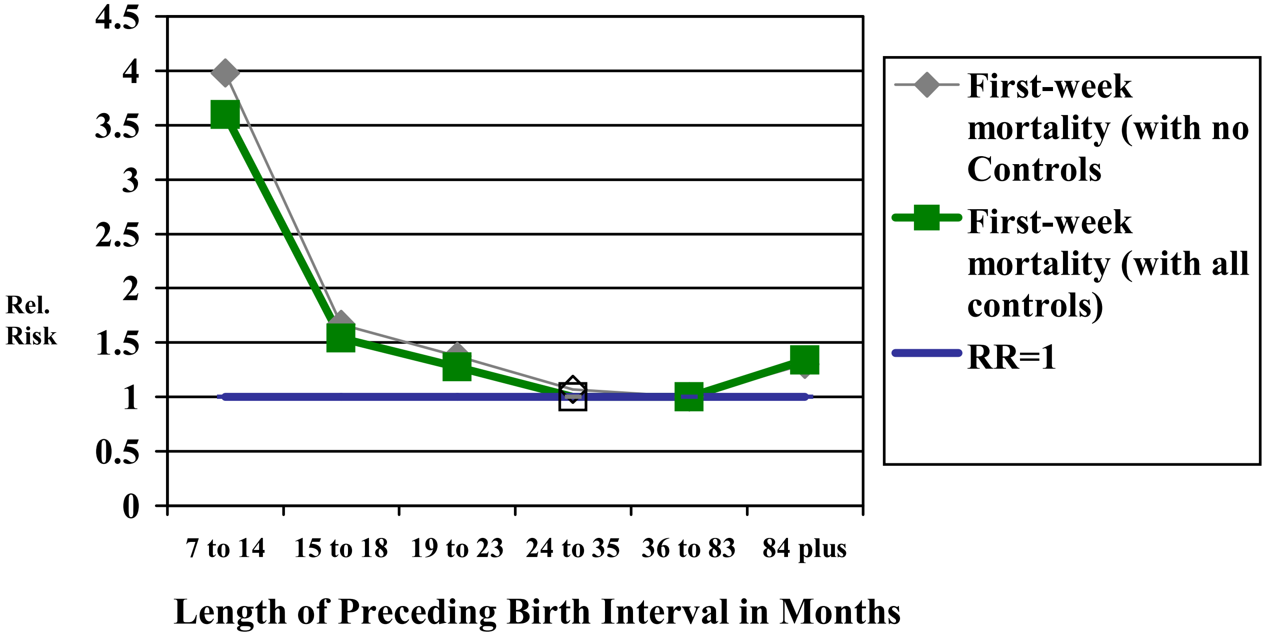

Figure 4. How length of preceding birth interval affects mortality during 2-4 weeks, with and without controls for other variables. (Hollow symbols indicate that the relative risk is not different than 1.0 at a significance level of p<.05.)

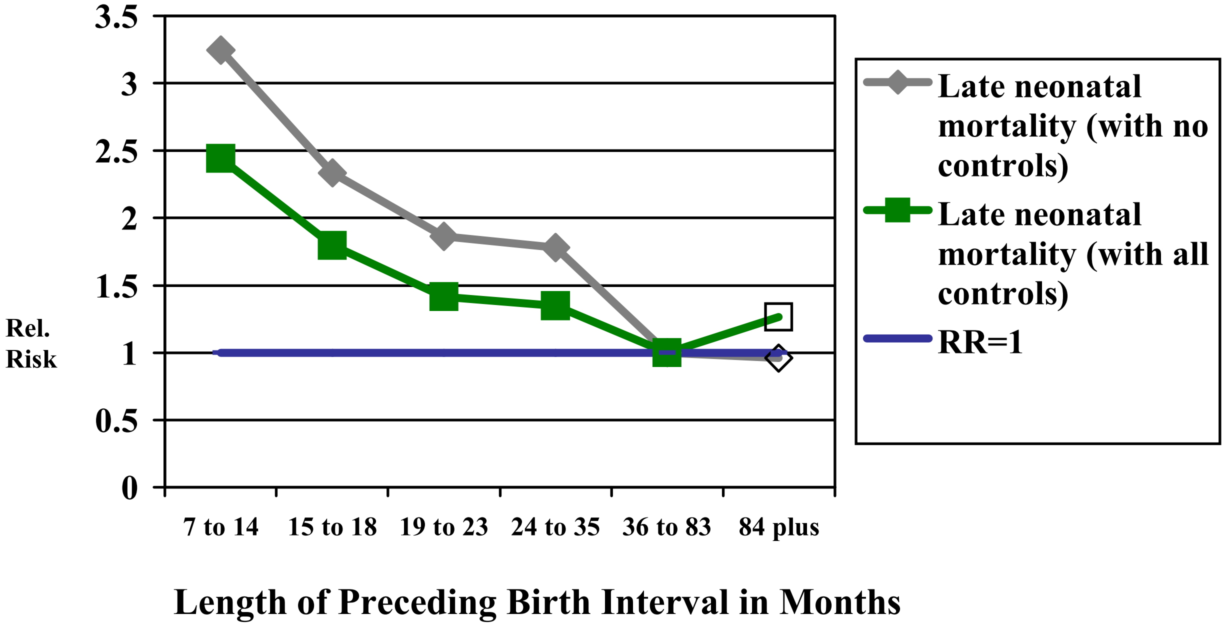

Figure 5. How length of preceding birth interval affects post-neonatal mortality, with and without controls for other variables. (Hollow symbols indicate that the relative risk is not different than 1.0 at a significance level of p<.05.)

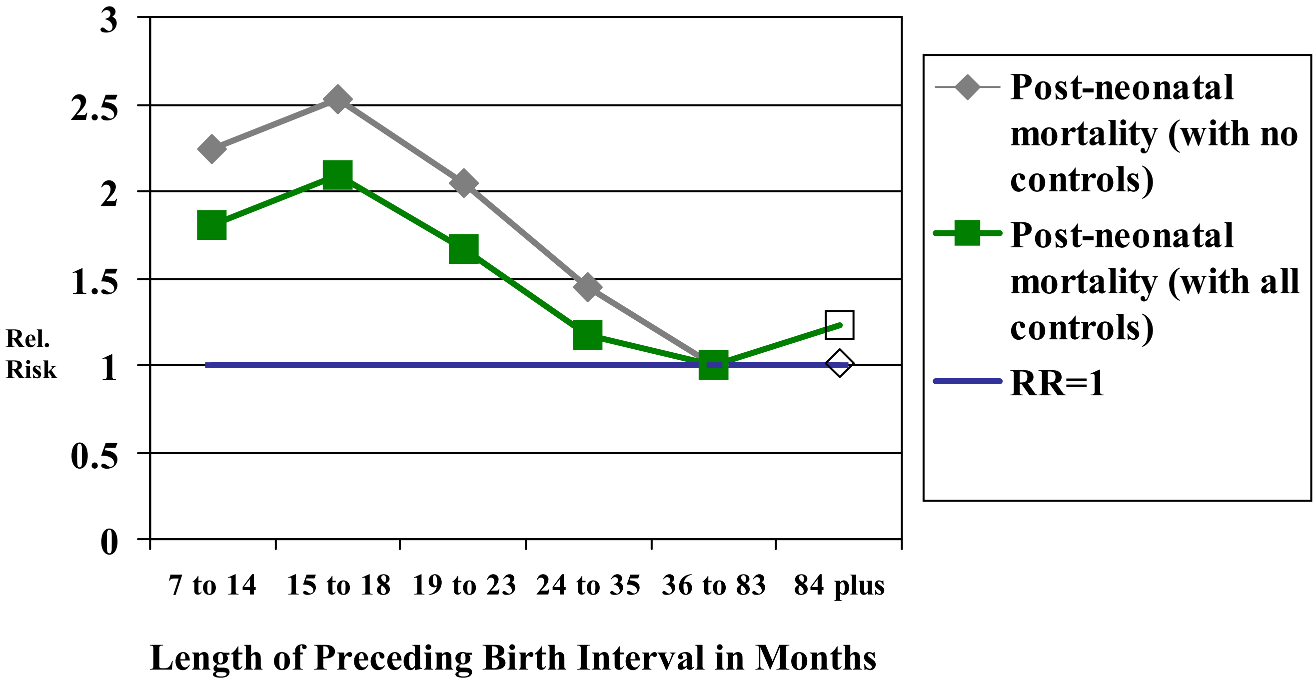

Figure 6. How length of preceding birth interval affects child mortality, with and without controls for other variables. (Hollow symbols indicate that the relative risk is not different than 1.0 at a significance level of p<.05.)

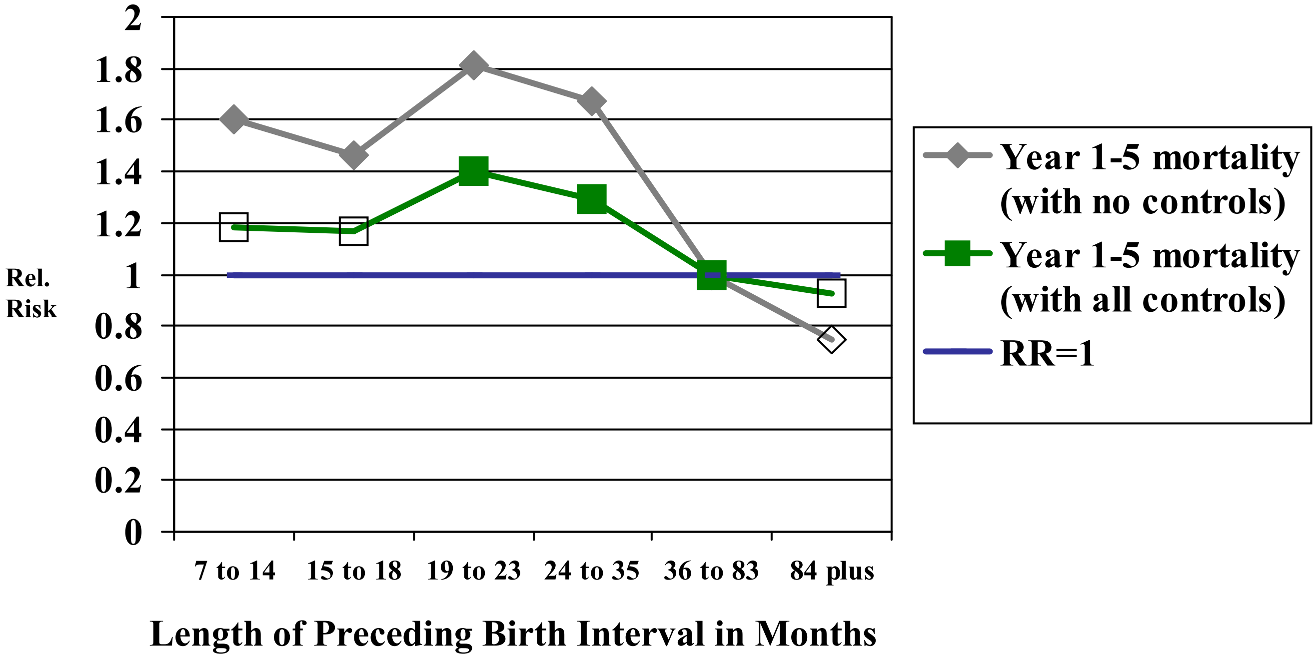

Figure 7. How length of preceding birth interval affects non-live birth outcome by MCH-FP area. (Hollow symbols indicate that the odds ratio is not different than 1.0 at a significance level of p<.05.)

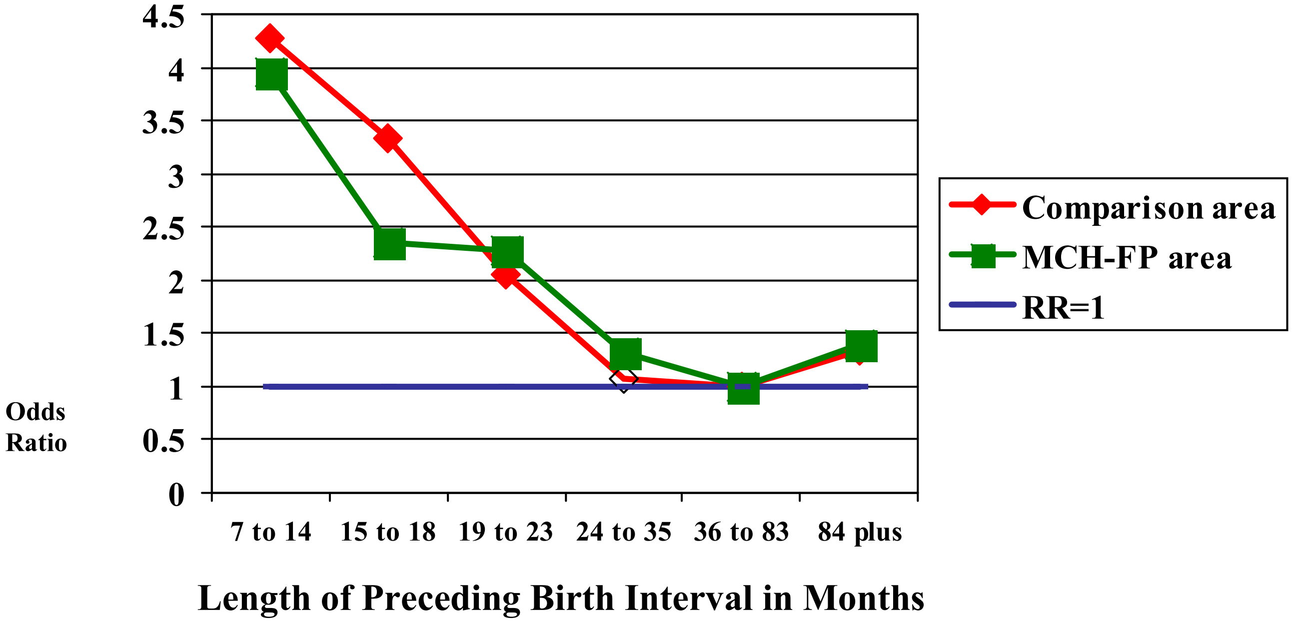

Figure 8. How birth parity at 8 or more varies by length of preceding birth interval.

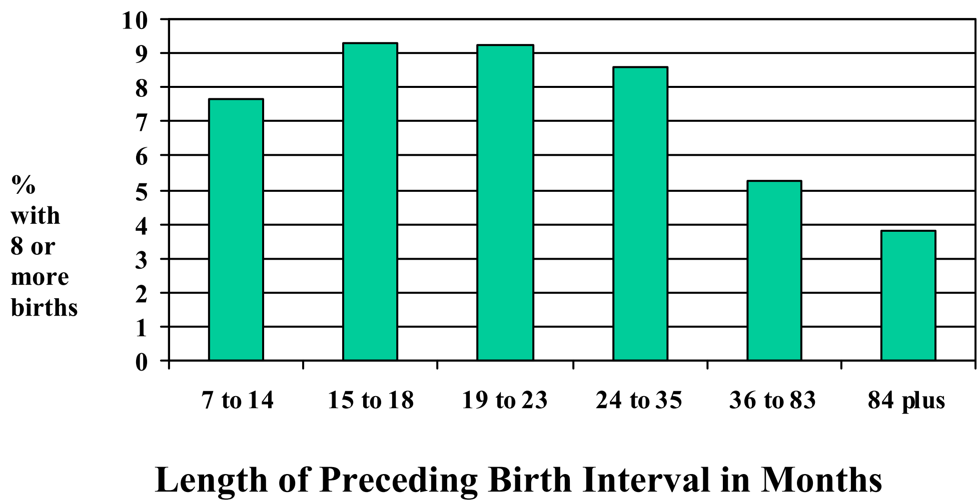

Figure 9. How mean age of woman varies by length of preceding birth interval.

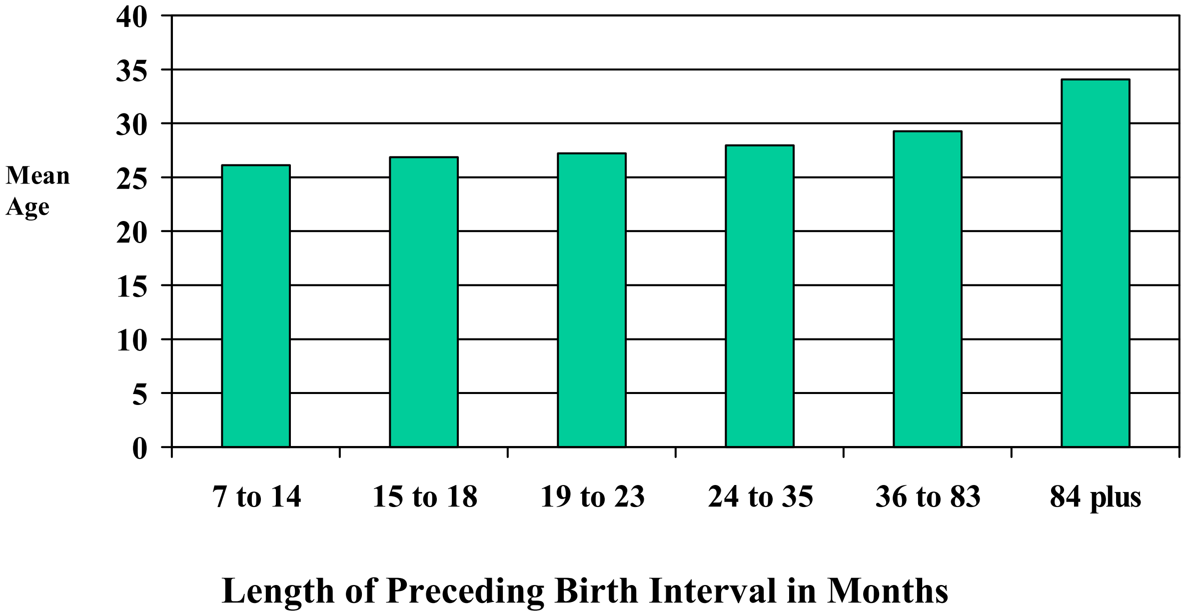

Figure 10. Percentage of pregnancies in the MCH-FP Area by length of preceding birth interval

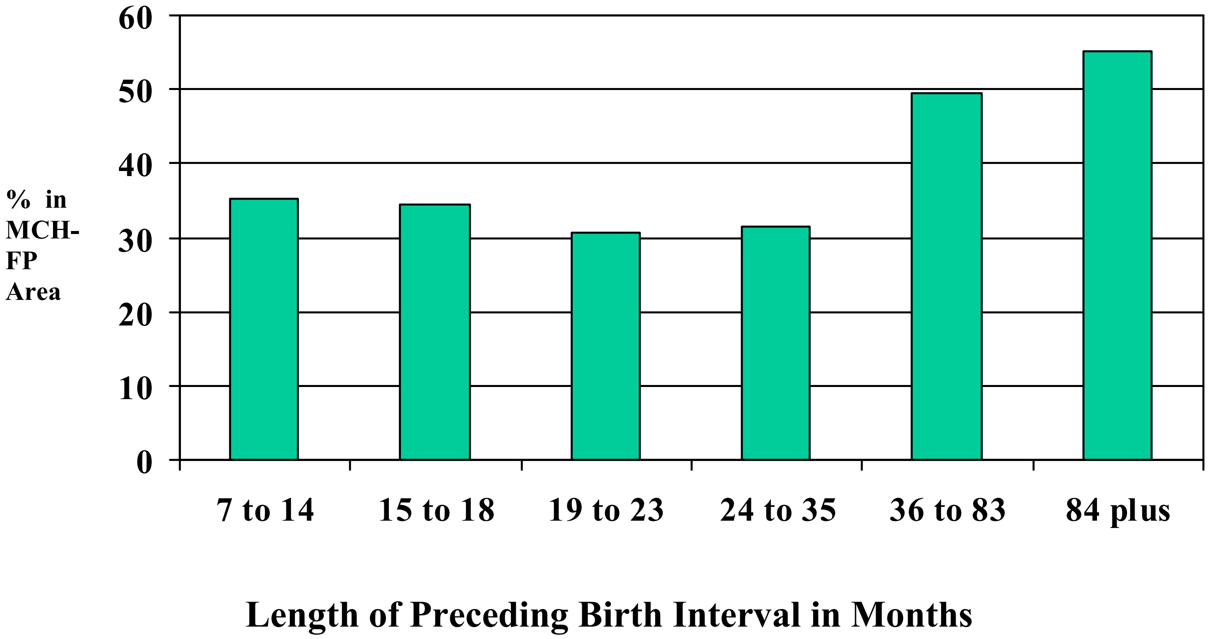

Figure 11. Whether the pregnant woman had a preceding pregnancy end in a non-live birth outcome by length of preceding birth interval.

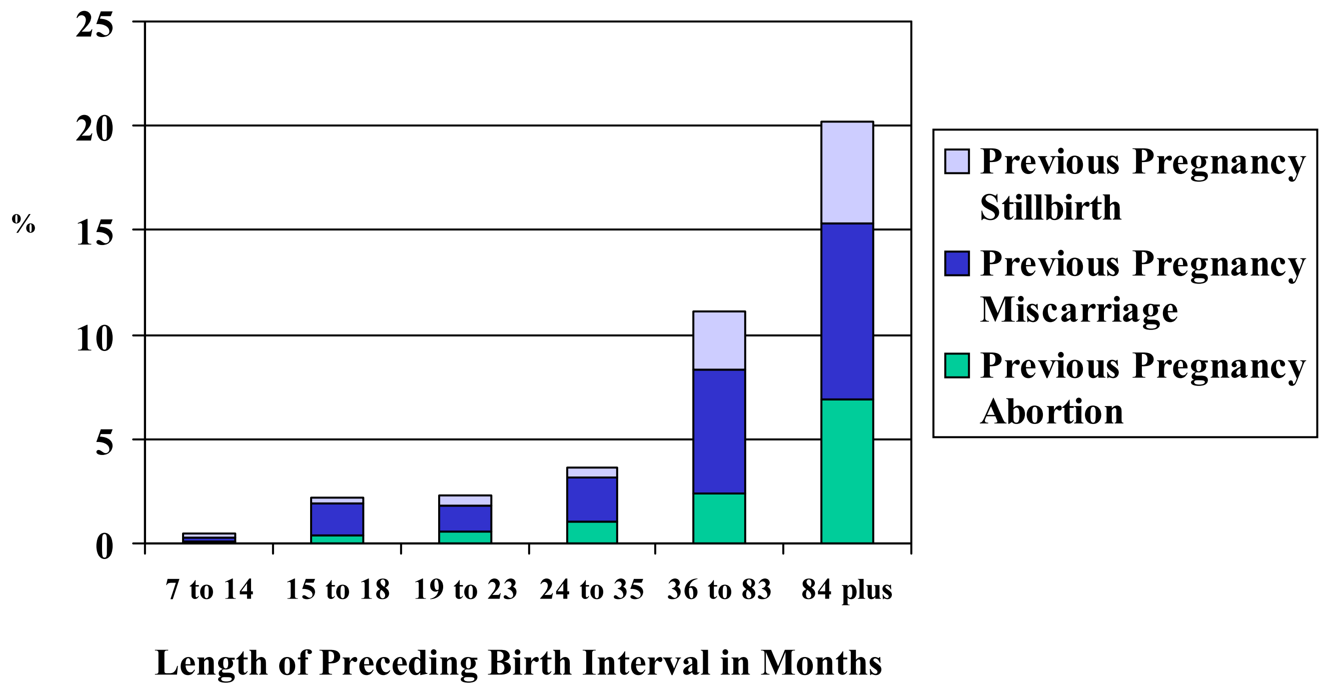

Figure 12. Relative magnitudes of the effects of short birth interval length, maternal age, maternal education, and housing space on pregnancy outcomes and infant and child mortality.

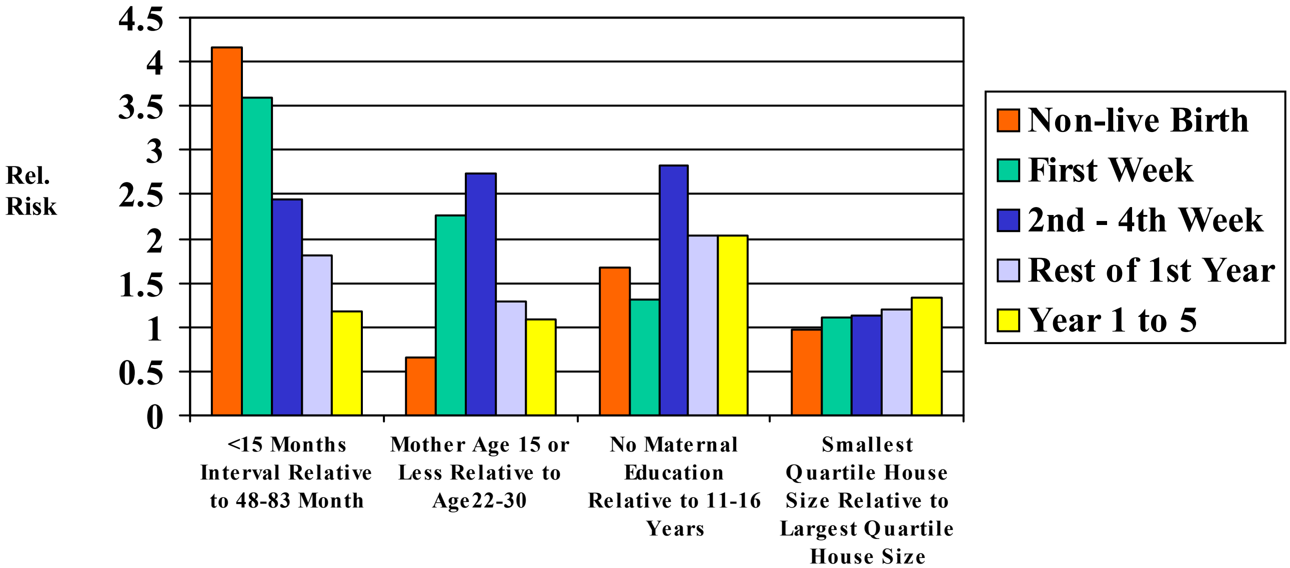

Table 1. Results of polytomous logistic regression on birth outcomes

	Abortion (n=145,839)				Miscarriage (n=145,839)				Stillbirth (n=145,839)			
Reference Category: Live Birth	Coef.	Odds Ratio exp(B)	s.e.		Coef.	Odds Ratio exp(B)	s.e.		Coef.	Odds Ratio exp(B)	s.e.	
Birth order =1	1.192	3.293	0.053	***	1.811	6.119	0.039	***	1.842	6.310	0.051	***
Inter-birth interval <15 Months	1.993	7.337	0.068	***	1.312	3.713	0.072	***	0.561	1.752	0.121	***
Inter-birth interval 15-18 Months	1.547	4.699	0.076	***	1.158	3.185	0.075	***	0.107	1.113	0.146	
Inter-birth interval 19-23 Months	0.971	2.640	0.066	***	0.833	2.300	0.060	***	0.278	1.321	0.092	**
Inter-birth interval 24-35 Months	0.080	1.083	0.053		0.262	1.299	0.045	***	0.035	1.036	0.060	
Inter-birth interval 36-83 Months												
Inter-birth interval 84 Plus	0.416	1.516	0.065	***	0.106	1.112	0.073		0.213	1.237	0.091	**
Inter-birth interval not known	-0.040	0.961	0.066		0.038	1.039	0.050		0.021	1.022	0.062	
Birth order = 2 or 3												
Birth order = 4 to 7	-0.043	0.958	0.047		-0.777	0.460	0.040	***	-0.689	0.502	0.053	***
Birth order = 8 plus	-0.673	0.510	0.077	***	-1.454	0.234	0.075	***	-1.320	0.267	0.097	***
MCH-FP Area	-0.619	0.538	0.034	***	-0.173	0.841	0.024	***	-0.170	0.844	0.032	***
Mother's age <16	0.377	1.458	0.179	*	-0.300	0.741	0.126	*	-1.633	0.195	0.283	***
Mother's age = 16 or 17	-0.473	0.623	0.099	***	-0.736	0.479	0.058	***	-1.119	0.326	0.084	***
Mother's age = 18 or 19	-0.829	0.437	0.075	***	-0.859	0.424	0.042	***	-1.041	0.353	0.056	***
Mother's age = 20 or 21	-0.738	0.478	0.064	***	-0.841	0.431	0.039	***	-0.859	0.424	0.050	***
Mother's age = 22 - 30												
Mother's age = 31- 39	1.406	4.079	0.045	***	1.174	3.235	0.040	***	1.140	3.126	0.051	***
Mother's age = 40 plus	2.767	15.911	0.071	***	2.184	8.881	0.073	***	2.013	7.489	0.094	***
Mother's education = 0												
Mother's education = 1 - 5 Years	0.228	1.256	0.038	***	0.005	1.005	0.028		-0.134	0.874	0.037	***
Mother's education = 6 - 10 Years	0.323	1.381	0.049	***	-0.242	0.785	0.038	***	-0.359	0.699	0.050	***
Mother's education = 11 - 16 Years	-0.006	0.994	0.120		-0.534	0.586	0.090	***	-0.822	0.440	0.129	***
Mother's education not known	-0.193	0.824	0.165		-0.278	0.757	0.090	**	-0.153	0.858	0.109	
Father's education = 0												
Father's education = 1 - 5 Years	0.109	1.115	0.043		-0.018	0.982	0.033		0.029	1.030	0.044	
Father's education = 6 - 10 Years	0.188	1.207	0.049	***	0.000	1.000	0.039		0.060	1.062	0.050	
Father's education = 11 - 16 Years	0.215	1.240	0.074	**	0.010	1.010	0.060		-0.029	0.972	0.082	
Father's education not known	-0.051	0.951	0.053		-0.085	0.918	0.039	*	-0.030	0.971	0.051	
Father absent	-0.010	0.990	0.046		-0.114	0.892	0.035	**	-0.154	0.857	0.046	***
Muslim												
Hindu or other religion	0.049	1.050	0.054		-0.152	0.859	0.040	***	0.051	1.052	0.048	
Housing space not known	0.096	1.101	0.085		0.102	1.108	0.060		0.040	1.041	0.081	

Housing space smallest quartile												
Housing space 2nd quartile	0.078	1.081	0.048		-0.058	0.943	0.034		-0.057	0.945	0.044	
Housing space 3rd quartile	0.130	1.139	0.049	**	-0.021	0.979	0.035		-0.022	0.978	0.045	
Housing space 4th quartile	0.297	1.346	0.048	***	-0.056	0.946	0.036		-0.046	0.955	0.047	
Previous pregnancy aborted	1.589	4.898	0.065	***	0.347	1.415	0.094	***	0.292	1.339	0.122	*
Previous pregnancy miscarried	-0.338	0.713	0.090	***	0.584	1.794	0.047	***	0.129	1.137	0.069	
Previous pregnancy stillbirth	-0.614	0.541	0.137	***	0.059	1.061	0.075		0.681	1.976	0.072	***
Years 1982-1986	-0.628	0.534	0.059	***	0.238	1.269	0.040	***	0.415	1.514	0.053	***
Years 1987-1991	-0.300	0.741	0.047	***	0.148	1.159	0.035	***	0.273	1.314	0.047	***
Years 1992-1996	-0.215	0.806	0.041	***	0.007	1.007	0.034		0.169	1.184	0.045	***
Years 1997-2002												
Constant	-4.103	0.017	0.066	***	-3.318	0.036	0.050	***	-3.885	0.021	0.066	***

*** p<.001 **p<.01 *p<.05

Table 2. Results of logistic regression on non-live birth, with and without controls

Non-live birth (n=145,839)	Model 1				Model 2			
	Coef.	Odds Ratio Exp(B)	s.e.		Coeff.	Odds Ratio Exp(B)	s.e.	
Birth order =1	0.870	2.387	0.022	***	1.699	5.467	0.028	***
Inter-birth interval <15 Months	0.986	2.680	0.046	***	1.427	4.168	0.048	***
Inter-birth interval 15-18 Months	0.765	2.150	0.051	***	1.118	3.059	0.052	***
Inter-birth interval 19-23 Months	0.442	1.556	0.040	***	0.751	2.119	0.042	***
Inter-birth interval 24-35 Months	-0.054	0.948	0.029		0.141	1.151	0.031	***
Inter-birth interval 36-83 Months								
Inter-birth interval 84 Plus	0.871	2.389	0.042	***	0.290	1.336	0.045	***
Inter-birth interval not known	-0.085	0.918	0.030	**	-0.041	0.959	0.036	
Birth order = 2 or 3								
Birth order = 4 to 7					-0.533	0.587	0.028	***
Birth order = 8 plus					-1.201	0.301	0.050	***
Comparison Area								
MCH-FP Area					-0.284	0.753	0.017	***
Mother's age <16					-0.423	0.655	0.102	***
Mother's age = 16 or 17					-0.789	0.454	0.046	***
Mother's age = 18 or 19					-0.897	0.408	0.032	***
Mother's age = 20 or 21					-0.822	0.440	0.029	***
Mother's age = 22 - 30								
Mother's age = 31- 39					1.241	3.458	0.028	***
Mother's age = 40 plus					2.360	10.591	0.049	***
Mother's education = 0								
Mother's education = 1 - 5 Years					0.023	1.024	0.020	
Mother's education = 6 - 10 Years					-0.137	0.872	0.027	***
Mother's education = 11 - 16 Years					-0.505	0.604	0.067	***
Mother's education not known					-0.191	0.826	0.068	**
Father's education = 0								
Father's education = 1 - 5 Years					0.033	1.034	0.024	
Father's education = 6 - 10 Years					0.080	1.084	0.028	
Father's education = 11 - 16 Years					0.076	1.079	0.043	
Father's education not known					-0.055	0.947	0.029	
Father absent					-0.096	0.908	0.025	***
Muslim								
Hindu or other religion					-0.047	0.954	0.028	
Housing space not known					0.079	1.082	0.045	
Housing space smallest quartile								
Housing space 2nd quartile					-0.028	0.972	0.025	
Housing space 3rd quartile					0.009	1.009	0.025	
Housing space 4th quartile					0.035	1.036	0.026	
Previous pregnancy live birth								
Previous pregnancy aborted					0.979	2.663	0.052	***
Previous pregnancy miscarried					0.285	1.329	0.038	***
Previous pregnancy stillborn					0.185	1.203	0.053	***
Year 1982					-0.037	0.964	0.061	

Year 1983					0.158	1.171	0.048	***
Year 1984					0.207	1.230	0.045	***
Year 1985					0.029	1.029	0.043	
Year 1986					0.041	1.042	0.043	
Year 1987					0.098	1.103	0.042	*
Year 1988					-0.003	0.997	0.042	
Year 1989					0.003	1.003	0.044	
Year 1990					0.100	1.105	0.041	**
Year 1991					0.080	1.084	0.042	
Year 1992					0.106	1.112	0.041	**
Year 1993					0.061	1.063	0.042	
Year 1994					-0.028	0.973	0.043	
Year 1995					-0.133	0.875	0.044	**
Year 1996					-0.114	0.892	0.045	*
Years 1997-2002								
Constant	-2.371	0.093	0.018	***	-2.587	0.075	0.036	***

*** p<.001 **p<.01 *p<.05

Table 3. Results of Cox proportional hazards models for subperiods of infant and child mortality with no controls

	First-week mortality (n=125,747)			2nd – 4th-week mortality (n=122,001)			Post-neonatal mortality (n=119,630)			Child mortality (n=106,444)		
	Haz. Ratio	Std. Err.		Haz. Ratio	Std. Err.		Haz. Ratio	Std. Err.		Haz. Ratio	Std. Err.	
Birth order =1	2.138	0.101	***	2.393	0.177	***	1.738	0.086	***	1.143	0.065	*
Inter-birth interval <15 Months	3.981	0.315	***	3.246	0.449	***	2.246	0.230	***	1.601	0.196	***
Inter-birth interval 15-18 Months	1.677	0.190	***	2.334	0.366	***	2.526	0.243	***	1.466	0.184	**
Inter-birth interval 19-23 Months	1.373	0.120	***	1.864	0.230	***	2.042	0.154	***	1.816	0.147	***
Inter-birth interval 24-35 Months	1.069	0.064		1.781	0.148	***	1.447	0.080	***	1.675	0.091	***
Inter-birth interval 36-83 Months												
Inter-birth interval 84 Plus	1.301	0.142	**	0.961	0.191		1.007	0.125		0.745	0.118	
Inter-birth interval not known	1.297	0.075	***	1.951	0.162	***	1.844	0.098	***	2.583	0.132	***

*** p<.001 **p<.01 *p<.05

Table 4. Results of Cox proportional hazards models for subperiods of infant and child mortality

	First-week mortality (n=125,747)			2^{nd} – 4^{th}-week mortality (n=122,001)			Post-neonatal mortality (n=119,630)			Child mortality (n=106,444)		
	Haz. Ratio	Std. Err.		Haz. Ratio	Std. Err.		Haz. Ratio	Std. Err.		Haz. Ratio	Std. Err.	
Birth order =1	1.864	0.112	***	1.922	0.176	***	1.697	0.106	***	1.029	0.074	
Inter-birth interval <15 Months	3.598	0.294	***	2.444	0.346	***	1.811	0.189	***	1.181	0.147	
Inter-birth interval 15-18 Months	1.544	0.177	***	1.797	0.286	***	2.095	0.205	***	1.166	0.148	
Inter-birth interval 19-23 Months	1.275	0.114	**	1.415	0.179	**	1.666	0.129	***	1.404	0.117	***
Inter-birth interval 24-35 Months	1.001	0.062		1.348	0.116	***	1.171	0.067	**	1.289	0.073	***
Inter-birth interval 36-83 Months												
Inter-birth interval 84 Plus	1.339	0.150	**	1.265	0.257		1.236	0.157		0.928	0.149	
Inter-birth interval not known	1.043	0.073		1.218	0.123	*	1.054	0.071		1.081	0.076	
Birth order = 2 or 3												
Birth order = 4 to 7	1.050	0.055		0.973	0.072		1.073	0.053		1.197	0.057	***
Birth order = 8 plus	1.373	0.133	***	1.214	0.165		1.547	0.132	***	1.450	0.124	***
Comparison Area												
MCH-FP Area	0.847	0.029	***	0.652	0.034	***	0.856	0.029	***	0.728	0.027	***
Mother's age <16	2.259	0.361	***	2.745	0.593	***	1.283	0.275		1.084	0.297	
Mother's age = 16 or 17	1.651	0.129	***	1.730	0.196	***	1.168	0.106		1.000	0.115	
Mother's age = 18 or 19	1.338	0.081	***	1.102	0.102		1.060	0.070		1.077	0.081	
Mother's age = 20 or 21	1.114	0.062		1.251	0.097	**	1.087	0.061		0.970	0.061	
Mother's age = 22 - 30												
Mother's age = 31-39	1.070	0.063		1.080	0.092		1.107	0.061		0.961	0.051	
Mother's age = 40 plus	1.186	0.148		1.058	0.193		1.247	0.134	*	0.714	0.088	**
Female	0.826	0.028	***	0.945	0.045		1.046	0.034		1.491	0.052	***
Mother's education = 0												
Mother's education = 1 - 5 Years	0.939	0.038		0.866	0.051	*	0.882	0.036	**	0.723	0.032	***
Mother's education = 6 - 10 Years	0.788	0.044	***	0.720	0.063	***	0.644	0.041	***	0.623	0.046	***
Mother's education = 11 - 16 Years	0.753	0.116		0.355	0.128	**	0.492	0.102	***	0.493	0.131	**
Mother's education not known	0.980	0.109		1.057	0.148		0.793	0.089	*	0.889	0.103	

Father's education = 0											
Father's education = 1 - 5 Years	0.935	0.045		0.934	0.068		0.974	0.049		0.975	0.052	
Father's education = 6 - 10 Years	0.962	0.055		0.953	0.082		0.908	0.055		0.893	0.059	
Father's education = 11 - 16 Years	0.980	0.089		0.676	0.110	*	0.937	0.094		0.849	0.099	
Father's education not known	0.911	0.050		0.950	0.074		1.019	0.055		1.059	0.060	
Father absent	1.026	0.050		1.020	0.074		0.987	0.051		0.986	0.057	
Muslim												
Hindu or other religion	1.202	0.061	***	1.217	0.091	**	1.027	0.055		0.762	0.048	***
Housing space not known	1.059	0.095		0.864	0.124		0.916	0.090		0.906	0.103	
Housing space smallest quartile												
Housing space 2nd quartile	0.958	0.046		0.909	0.062		0.884	0.040	**	0.920	0.042	
Housing space 3rd quartile	1.012	0.049		0.975	0.068		0.866	0.041	**	0.794	0.040	***
Housing space 4th quartile	0.908	0.047		0.879	0.066		0.831	0.042	***	0.749	0.041	***
Previous pregnancy live birth												
Previous pregnancy aborted	0.862	0.152		1.398	0.289		0.759	0.145		0.820	0.165	
Previous pregnancy miscarried	1.258	0.100	**	0.904	0.123		0.950	0.086		0.884	0.091	
Previous pregnancy stillbirth	1.421	0.146	***	0.956	0.175		1.305	0.141	**	0.977	0.134	
Year 1982	1.494	0.146	***	2.684	0.367	***	2.584	0.254	***	4.938	0.478	***
Year 1983	1.410	0.119	***	2.251	0.282	***	2.925	0.247	**	3.400	0.321	***
Year 1984	1.406	0.117	***	2.253	0.278	***	2.581	0.216	***	2.555	0.244	***
Year 1985	1.154	0.095		2.480	0.278	***	2.020	0.166	***	2.190	0.196	***
Year 1986	1.001	0.087		2.218	0.255	***	1.815	0.152	***	1.789	0.165	***
Year 1987	1.071	0.090		1.874	0.225	***	2.047	0.164	***	1.488	0.143	***
Year 1988	1.152	0.095		1.828	0.222	***	1.755	0.147	***	1.330	0.132	**
Year 1989	1.118	0.096		1.842	0.230	***	1.589	0.142	***	1.519	0.148	***
Year 1990	1.170	0.098		1.798	0.224	***	1.788	0.152	***	1.388	0.138	***
Year 1991	1.196	0.100	*	2.288	0.267	***	2.229	0.180	***	1.696	0.165	***
Year 1992	1.233	0.103	*	1.485	0.204	**	1.558	0.144	***	1.271	0.136	*
Year 1993	1.319	0.109	***	1.579	0.215	***	1.422	0.138	***	1.160	0.130	
Year 1994	1.059	0.094		1.379	0.196	*	1.528	0.143	***	1.344	0.143	**
Year 1995	0.982	0.091		1.152	0.179		1.331	0.133	**	1.331	0.144	**
Year 1996	1.043	0.097		1.193	0.189		1.220	0.130		1.236	0.141	
Years 1997-2002												

*** p<.001 **p<.01 *p<.05