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ARTICLE

Effects of preceding birth intervals on neonatal, infant and under-five years mortality and nutritional status in developing countries: evidence from the demographic and health surveys

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Under five mortality;
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Abstract

Objective: This paper examines the association between birth intervals and infant and child mortality and nutritional status. *Methods:* Repeated analysis of retrospective survey data from the Demographic and Health Surveys (DHS) program from 17 developing countries collected between 1990 and 1997 were used to examine these relationships. The key independent variable is the length of the preceding birth interval measured as the number of months between the birth of the child under study (index child) and the immediately preceding birth to the mother, if any. Both bivariate and multivariate designs were employed. Several child and mother-specific variables were used in the multivariate analyses in order to control for potential bias from confounding factors. Adjusted odds ratios were calculated to estimate relative risk. *Results:* For neonatal mortality and infant mortality, the risk of dying decreases with increasing birth interval lengths up to 36 months, at which point the risk plateaus. For child mortality, the analysis indicates that the longer the birth interval, the lower the risk, even for intervals of 48 months or more. The relationship between chronic malnutrition and birth spacing is statistically significant in 6 of the 14 surveys with anthropometric data and between general malnutrition and birth spacing in 5 surveys. However, there is a clear pattern of increasing chronic and general undernutrition as the birth interval is shorter, as indicated by the averages of the adjusted odds ratios for all 14 countries. *Conclusion:* Considering both the increased risk of mortality and undernutrition for a birth earlier than 36 months and the great number of births that occur with such

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short intervals, the author recommends that mothers space births at least 36 months. However, the tendency for increased risk of neonatal mortality for births with intervals of 60 or more months leads the author to conclude that the optimal birth interval is between 36 and 59 months. This information can be used by health care providers to counsel women on the benefits of birth spacing.

1. Introduction

1.1. Purpose

Since at least 1923, the deleterious effect of short interbirth and/or interpregnancy intervals for maternal and child health has been investigated. The effect of short intervals has been demonstrated many times to be one of the most important factors affecting the mortality of infants and young children. Little research has been done, however, on determining the optimal birth interval rather than establishing the relationship between birth intervals and mortality. It is the purpose of this paper to determine whether there is an "optimal" interval for the mortality of children under age 5 years and, if so, to establish the optimal spacing "window" in order to guide mothers. As such, this paper reports on the analysis of the effects of birth spacing on infant and child mortality, and on nutritional status, controlling for the effects of potentially confounding variables.

1.2. History and literature review

The earliest studies of the effect of the length of birth interval on young child mortality were based on field studies of registration records in U.S. cities [1,2]. Although uncontrolled for confounding factors, both these studies showed that short preceding birth intervals resulted in higher infant mortality rates. Eastman [3] studying births occurring at Johns Hopkins University Hospital from 1936 to 1943, was the first to adjust for length of gestation. He found that only very short birth intervals, less than 12 months, had any effect on children or mothers. Yerushalmy [4] was the first to do a national-level study, using over seven million births in the United States from 1937 to 1941. His indirect estimates of average birth interval (based on age and parity of mother), controlled for race, found that relatively short intervals and relatively long intervals are associated with higher stillbirth rates and that the moderate intervals lead to the lowest rates. Prematurity at a national level in England and Wales was studied by Douglas [5] using registered births occurring to the manual labor social class during 1 week in 1946. After standardizing for age, Douglas found that women who space their pregnancies more than 2, but not more than 6 years apart, are least likely to have premature babies.

A comprehensive investigation of the effect of multiple birth intervals, including preceding and subsequent intervals was done by Hobcraft, McDonald, and Rutstein [6]. This study based on retrospective birth histories in 26 World Fertility Surveys used counts of births in intervals prior to and subsequent to the index child, thus allowing for multiple short intervals. The study was also one of the earliest to control for a series of confounding factors such as prior deaths, maternal age, birth order, and socio-economic status. In this study, the lowest relative risk of dying at age under 5 years occurred to children whose mothers had one prior birth in the preceding 2 to 6 years. As the number of births in the 0—2 and 2—6 year preceding periods increased, the relative risk increased. The same was true for a subsequent birth within 30 months. The highest risk of mortality under age 5 years occurred to children who had 3 prior siblings 2 to 6 years earlier, a prior sibling within the preceding 2 years and a subsequent sibling in the 30 months following the birth of the index child.

Several studies done since the 1980s have used data from the Matlab, Bangladesh demographic surveillance project. In a prospective cohort study, Koenig et al. [7] found that preceding birth interval effects were concentrated in early infancy and that subsequent birth interval effects were concentrated in early childhood (ages 1 to 4 years). This study controlled for sex of child, maternal age, birth order, maternal education, housing area, death of the preceding child, and time. The under-five mortality rate fell from 280 deaths per 1000 births for children with a preceding birth interval of less than 2 years to 174 per 1000 for births after an interval of 4 or more years. Miller et al. [8], Zenger [9], Alam [10], Alam and David [11], Mozumder, Barkat-e-Khuda, and Kane [12] used either dichotomies (short vs. long interval) or a log transformation of the length of the birth interval to study young child mortality in relationship to birth interval. Mostafa, Foster, and Fauveau [13] used preceding pregnancy interval to study perinatal mortality. All the studies were multivariate and found a significant and important relationship between interval length and mortality.

An earlier study based on 17 early (phase 1) Demographic and Health Surveys done by Boerma and Bicego [14] attempted to find the pathways of influence of birth intervals on young child mortality. The study used unconventional mortality intervals of 1—6 months and 7 to 23 months as well as neonatal mortality. In addition, the study included nutritional status of children, morbidity, breastfeeding and health care as outcomes. Their "results indicate that prenatal mechanisms are more important than postnatal factors, such as sibling competition, in explaining the causal nature of the birth interval effect."

Studies of the effect on mortality of interbirth or interpregnancy intervals that are based on hospital records or vital registrations are limited to mortality in pregnancy, during delivery or shortly thereafter. They also are quite limited in the scope of potentially confounding factors that are recorded. Moreover, in developing countries, where many if not the majority of births do not occur in health facilities, they are biased to urban areas and to mothers that are higher in education and economic status. While surveys have their own limitations, for example, possibly less accurate dating of births and in some cases, the absence of gestational length and pregnancies that did not end in a live birth, they have advantages in data on mortality beyond the neonatal period and in a larger set of variables to control for confounders.

2. Methods and data

2.1. Methods

The methodology used in this study is repeated analysis of retrospective survey data of the Demographic and Health Surveys (DHS) program. In certain analyses, the data of separate surveys have been analyzed together. For infant and child mortality, the dependent variables are true cohort probabilities of mortality based on survival status and age at death for children who have had full exposure to dying during the given age ranges of mortality.

For nutritional status, the dependent variable is the percent of young children who are stunted, wasted, or who are underweight. As part of the interviewing procedure, the DHS surveys routinely collect the height and weight of children under age 5 years. Together with the child's age, this information can be used to assess the nutritional status of children when compared to a reference standard using standard deviation values (z-scores). The DHS data are compared to the NCHS/CDC/WHO international reference standards for height for age, weight for age, and weight for height. Children whose z-scores are less than two standard deviations below the mean (-2 S.D.) on the reference standard are considered moderately or severely undernourished. Chronic undernutrition, or stunting, is determined by a height-for-age z-score below two standard deviations below the mean. Acute undernutrition, or wasting, is measured by a z-score less than -2 S.D. for weight for height, and overall undernutrition, or underweight, is measured by a z-score less than -2 S.D. for weight for age.

The key independent variable is the length of the preceding birth interval measured as the number of months between the birth of the child under study (index child) and the immediately preceding birth to the mother, if any. Both bivariate and multivariate designs were used. The multivariate analysis is repeated for several surveys and the results are combined for each of the mortality age ranges. The summary results are produced by using a weighted average of the coefficients, with the weights being the inverse of the square of the standard errors (variances) in the individual analysis. The summary standard error of the coefficients is calculated using the assumption of variance for independent samples. The coefficients are exponentiated to give the relative odds ratios, and the 95% confidence interval of the relative odds ratio is calculated by adding or subtracting 1.96 times the summary standard error from the coefficient before exponentiation.

2.1.1. Multivariate analysis

There are a number of factors that may potentially confound the relationship between birth intervals and young child mortality. These have been cited by a number of authors (for example see [15]). Birth-specific confounders include the age of the mother at the birth, the birth order, the multiplicity of the birth, the sex of the child, use of health care services, breastfeeding, and wantedness of the birth. Mother-specific confounders include socio-economic status and type of area of residence. In order to control for the potential of confounding, variables representing these factors have been used in multiple logistic regression analyses.

It is well known that the mother's age at birth and birth order are related to children's mortality (see for example, [16,17]). They may also be related to birth interval length through biological and volitional linkages. Fecundability declines with age, and older mothers and those with more children may restrict their fertility through contraception and decreases in sexual relations.

Male children have higher mortality in most cultures. In others, neglect and infanticide may invert this biological relationship. In these cultures, birth intervals may also be associated with the child's sex as families strive to meet their gender goals.

The use of health care services can be related to both mortality, through preventive and curative services and availability and use of contraception [18]. Information is not available for most of the births from the DHS surveys on the use of contraception between births. Therefore, type of prenatal care provider, delivery attendant, and number of tetanus toxoid vaccinations during pregnancy are used as measures of access to both health services for children and contraception. Moreover, these variables are more directly related to perinatal and neonatal mortality.[1]

Breastfeeding provides a potentially confounding link between mortality and birth intervals. External factors, such as household environment, can raise the mortality of both the index child and the next older sibling. The death of the older sibling will cut short the duration of breastfeeding and postpartum amenorrhea, leading to an increased risk of a short birth interval. Taking account of the survival of the preceding child controls for the breastfeeding—amenorrhea effect and for the external mortality relationships. However, the risk of death of the preceding child can also be raised by its short subsequent interval [6], so that controlling for any death may result in an over-correction. The death of the preceding child can only affect the preceding birth interval if the death occurs before the conception of the index child. In order to avoid over-correction, only deaths of the preceding child before the index child's conception will be controlled in these analyses.

An unwanted child, especially one due to contraceptive failure, may suffer more neglect than wanted children. To control for these effects, the wantedness of the child and whether the child resulted from a failure of contraception are used as controls in the analyses. Since these variables are only available for births that occurred in the 5 years preceding the survey, they are used for the neonatal and infant and nutritional status analyses, but they cannot be used for under-five mortality analyses because those analyses are based on children born 5 to 15 years prior to the surveys. Moreover, information on births resulting from a failure of contraception is not available for countries with low contraceptive prevalence and in the India and Nepal surveys.[2]

Access to health services and to contraceptives, physical and social environments, and socio-economic status is associated with both child mortality and the spacing of births. To control for these effects, four variables are used in the analyses: mother's level of education (none, primary, secondary or higher), type of area of residence (urban or rural), wealth (quintile of wealth index [19,20]), and type of drinking water supply and toilet facility.[3]

To ascertain the adjusted odds ratios, binary logistic analysis is employed using the SPSS version 10.0 program [21]. Cases are individual children. The dependent variable is the survival of the index children during the mortality interval of interest for children surviving to the beginning of the interval. The principal independent variable is the preceding birth interval calculated as the difference in birth dates (year and month) between the birth of the preceding child and of the index child and grouped into 6-month intervals. First births are included as a separate category. The birth interval 36 to 41 months is used as the reference category. The variables given above are used as controls for confounding relationships. Missing values for each independent variable are included as separate categories. The DHS surveys do not permit missing data on survival or age at death. The results

[1] In order to avoid reverse causality, other vaccinations cannot be used for neonatal and infant mortality because children may die before they are of age to get the vaccination. Infant deaths usually consist of about half neonatal and half post neonatal deaths, but the majority of post-neonatal mortality comes in the early months and therefore many deaths are also be before the age at which vaccinations for DPT, polio, and measles are given. Indeed in Latin America measles are given after the first year of life. The children included in the under-five years analyses are all born 5 or more years ago (to avoid censoring of mortality exposure), and the DHS does not collect vaccination information for children born more than 5 years ago.

[2] There are no calendar data from Côte d'Ivoire, Ghana, India, Kenya, Nepal, Nigeria, Tanzania, Uganda, and Zambia.

[3] The absence of the father (or mother's spouse/partner) may also be related to both child mortality and birth intervals. Children whose father is absent may have lessened resources for childcare and health service utilization. Birth intervals may also be longer if the mother has less frequent sexual relations due to the absence. However, in the DHS surveys is not possible to ascertain the father's presence in the household at the time of death for children who have died nor whether the child was living away from home at the time of death.

presented are exponentiated coefficients to obtain the adjusted odds ratios.

2.2. DHS data used in the study

The data used in this study come from 17 countries surveyed in the Demographic and Health Surveys (DHS) program. This program of surveys in developing countries started in 1984 and is financed principally by the United States Agency for International Development. The DHS surveys are based on scientifically selected samples of households and women of reproductive age to produce nationally representative data on fertility, infant, and child mortality, child and reproductive health, nutritional status, family planning, and on many other health-related issues. In many countries men of reproductive age are also interviewed. Each country survey is conducted by individual country survey organizations with technical assistance in design, sampling, training, fieldwork, data processing, tabulation and report generation provided by ORC Macro.[4]

The household section of the DHS collects general household information, such as location, possessions, and services. A roster of household members collects information on sex, age, relationship to the head, de-facto and de-jure status, and education level. Women between the ages of 15 and 49 years, inclusive, who slept in the dwelling the night before the interview are selected for interviewing with an individual questionnaire.[5]

The individual women's questionnaire contains a complete birth history with birth dates, sex, multiplicity of birth, survival status, and age at death if not surviving, for each child. In some countries, a month-by-month reproductive calendar of the preceding 5 years gives information on pregnancies by duration and type of termination[6]. For each child under 5 years of age, information is collected on prenatal and delivery care, birth weight and size, vaccinations received, feeding and breastfeeding, and morbidity status and treatment. Nutritional and anemia status of the women and children under 5 years are ascertained through anthropometric measurement and finger pricks, respectively.

All interviews are conducted face-to-face by specially trained women interviewers. Anthropometic measurements are taken using internationally standard height boards and UNICEF scales. Blood hemoglobin levels are measured using Hemocue devices. Specially trained staff, in many cases, public health nurses, carries out the anthropometric and anemia measurements.

The quality of the DHS data are among the highest for data on births and infant and child deaths in the developing countries (see [22,23]). There is evidence for a small amount of digit preference for 12 months in the declaration of age at death, so that infant and postneonatal rates may be understated and child mortality overstated by up to 5%. No effect on neonatal or under-five years mortality rates has been found. There is also evidence for some transference of births to a year earlier in order to avoid asking a long health section for young children. For most surveys, this boundary is at five calendar years prior to the survey. In other surveys, the health section eligibility boundary is three or four calendar years prior to the survey. Since most of the questions are for children living at the time of the survey, the effect of the transference would be to slightly lower mortality rates for short preceding birth intervals, but only for children born in the calendar year after the boundary.

The 17 DHS surveys selected for this analysis represent the following countries: Bangladesh, Bolivia, Egypt, Ghana, Guatemala, India[7], Indonesia, Côte d'Ivoire, Kenya, Morocco, Nepal, Nigeria, Peru, Philippines, Tanzania, Uganda, and Zambia. These countries are those that were high priority countries for USAID activities at the time of carrying out the analysis.

2.3. Preceding birth intervals

The distributions of preceding birth intervals are given in Table 1. Of all births considered, almost 23% were first births, based on the weighted average. Among second and higher order births, the median number of months since the preceding birth was 25.7 months. Very short intervals of less than 18 months between births accounted for 16% of the birth intervals of second or higher order births. While more than a third of birth intervals

[4] The Demographic and Health Surveys project originally began at Westinghouse Corporation's Institute for Resource Development, which was acquired by Macro Systems, later renamed Macro International, Opinion Research Corporation acquired Macro International in 1999.

[5] In some countries of the Near East and Asia, only ever-married women are considered eligible for interview.

[6] Bangladesh, Bolivia, Egypt, Guatemala, Indonesia, Morocco, Peru, and the Philippines included a reproductive calendar.

[7] Due to the size of the India data set, in which almost 185,000 births were recorded in the 15-year period prior to the survey, a 20% subsample of births was used.

Table 1 Distribution of births 60 to 179 months prior to survey by months since preceding birth

Survey		Preceding birth interval in months									1st births	Total	*N*
		<18	18–23	24–29	30–35	36–41	42–47	48–53	54–59	60+			
Bangladesh	1996–1997	9.5	11.2	15.6	11.3	10.0	5.5	3.8	2.2	6.4	24.5	100.0	13,343
Bolivia	1994	15.3	15.7	15.3	9.8	6.5	4.0	3.0	2.0	6.7	21.7	100.0	11,094
Côte d'Ivoire	1994	11.2	14.7	17.8	11.8	5.8	4.7	3.0	2.0	5.8	23.2	100.0	11,645
Egypt	1995	18.9	13.4	13.9	9.7	7.2	4.6	3.3	2.2	6.3	20.4	100.0	25,407
Ghana	1993	6.3	11.7	14.0	13.3	9.6	6.2	4.5	2.5	7.9	24.1	100.0	6178
Guatemala	1995	14.0	15.6	18.2	11.4	6.9	4.3	2.9	2.0	5.7	19.0	100.0	17,290
India	1992–1993	12.0	13.8	16.7	9.8	7.8	4.0	3.0	1.8	5.0	26.1	100.0	24,702
Indonesia	1994	11.2	12.9	14.1	9.3	7.3	4.8	3.6	2.7	8.5	25.6	100.0	40,326
Kenya	1993	12.5	16.4	19.7	11.8	7.7	3.9	2.6	1.7	4.0	19.6	100.0	11,248
Morocco	1995	15.6	15.1	18.1	11.1	7.1	3.9	3.0	2.0	5.2	18.9	100.0	10,123
Nepal	1996	9.6	13.7	17.8	12.3	9.8	4.9	2.8	1.9	4.6	22.7	100.0	13,174
Nigeria	1990	11.2	18.5	21.0	10.4	6.5	3.3	2.3	1.3	4.5	21.0	100.0	13,681
Peru	1996	13.8	13.2	14.8	9.2	6.3	4.3	3.3	2.4	8.3	24.4	100.0	32,327
Philippines	1993	16.5	15.8	15.0	9.5	5.9	4.1	2.6	2.1	5.6	22.9	100.0	16,472
Tanzania	1996	8.2	12.5	16.7	13.8	9.8	5.1	3.9	2.0	6.1	21.8	100.0	10,821
Uganda	1995	11.6	17.5	19.6	11.0	6.5	3.8	2.3	1.4	4.3	21.9	100.0	10,139
Zambia	1996	7.3	13.5	20.4	13.3	8.0	4.7	3.3	1.8	5.5	22.2	100.0	10,473
Average (weighted)		12.6	14.2	16.4	10.6	7.4	4.4	3.2	2.1	6.3	22.9	100.0	278,443

were less than 24 months in duration, more than another third occurred with durations of 24 to 35 months, resulting in almost 70% of second and higher order births being at durations of less than 36 months years. Thus, more than half of all births, including first births, had an older sibling born within less than 3 years earlier.

It has been postulated that premature births are a confounding factor in the analysis of neonatal, post-neonatal, and infant mortality rates by shortening the birth-to-birth interval through a shortened length of gestation. Because premature births are known to have high rates of mortality, the mortality effects of short birth intervals (as opposed to short pregnancy intervals), may be biased upwards since they would contain a disproportionately high number of premature births. The shorter is the interval, the more likely that the proportion of premature births is higher. The analyses that have shown to be most affected are those with birth intervals of under 12 or under 15 months. Since we cannot control for the length of gestation in all the countries, due to lack of data, we examine its potential effect on the results given here by examining the effect that adjusting for gestational length would have on the classification of birth into the birth intervals using the data from the reproductive calendar. Table 2 presents the results of this exercise.

Table 2 Effect of premature births on preceding birth intervals (percent of intervals shifted by using 9 months instead of actual gestation)

Preceding birth interval (months)	Percent shifted up
7–17	0.1
18–23	0.2
24–29	0.2
30–35	0.2
35–41	0.2
42–47	0.1
48–53	0.1
54–59	0.0
60–119	–

As can be seen from Table 2, at most about 0.2% of births had been shifted into a longer birth interval due to the assumption of a nine-month gestation rather than actual gestation. For the shortest birth interval group used here only 0.1% of births have been misclassified. Even if premature births had much higher rates of mortality, their combined effect is quite small due to the lack of misclassification (99.9% correctly classified).

2.4. Bivariate results

2.4.1. Infant and child mortality

The DHS surveys collect age at death for non-surviving children in three scales: for children who died at less than 1 month, age in days is collected. For non-surviving children dying within 2 years of birth, age at death in number of months is collected. Number of years is used for children who died at an age of 2 or more years since birth. Dates of birth of children are given in calendar year and month. Preceding birth intervals are calculated by the difference between the date of birth of the index child and the immediately preceding child. Only singleton births are used for the index children. Since only some of the countries have information on pregnancy intervals

Table 3 Under-five mortality rates by duration of preceding birth interval, births 60 to 179 months prior to survey

Survey	Preceding birth intervals									First birth	Total	*N*
	<18 months	18—23 months	24—29 months	30—35 months	36—41 months	42—47 months	48—53 months	54—59 months	60+ months			
Bangladesh (1996—1997)	0.222	0.154	0.127	0.101	0.095	0.094	0.091	0.068	0.072	0.147	0.127	13,343
Bolivia (1994)	0.223	0.171	0.135	0.114	0.092	0.065	0.075	0.053	0.073	0.099	0.128	11,094
Côte d'Ivoire (1994)	0.242	0.170	0.135	0.110	0.083	0.085	0.067	0.067	0.088	0.164	0.138	11,645
Egypt (1995)	0.086	0.044	0.030	0.028	0.021	0.016	0.016	0.019	0.028	0.047	0.042	25,407
Ghana (1993)	0.234	0.160	0.145	0.117	0.088	0.087	0.074	0.054	0.070	0.134	0.122	6178
Guatemala (1995)	0.171	0.096	0.084	0.070	0.059	0.057	0.051	0.057	0.053	0.090	0.089	17,290
India (1992—1993)	0.194	0.120	0.103	0.085	0.073	0.076	0.050	0.048	0.053	0.106	0.105	24,702
Indonesia (1994)	0.189	0.111	0.101	0.088	0.066	0.063	0.050	0.051	0.054	0.082	0.091	40,326
Kenya (1993)	0.156	0.098	0.076	0.081	0.076	0.069	0.056	0.058	0.053	0.091	0.089	11,248
Morocco (1995)	0.185	0.088	0.080	0.061	0.062	0.049	0.044	0.027	0.043	0.095	0.088	10,123
Nepal (1996)	0.261	0.190	0.160	0.117	0.102	0.089	0.056	0.073	0.064	0.147	0.145	13,174
Nigeria (1990)	0.251	0.187	0.172	0.152	0.115	0.131	0.108	0.095	0.070	0.153	0.162	13,681
Peru (1996)	0.167	0.108	0.078	0.063	0.046	0.046	0.046	0.046	0.047	0.058	0.077	32,327
Philippines (1993)	0.101	0.061	0.058	0.045	0.044	0.040	0.037	0.051	0.037	0.047	0.058	16,472
Tanzania (1996)	0.224	0.170	0.132	0.094	0.090	0.093	0.073	0.103	0.086	0.137	0.126	10,821
Uganda (1995)	0.206	0.153	0.122	0.105	0.090	0.103	0.077	0.061	0.079	0.151	0.133	10,139
Zambia (1996)	0.285	0.212	0.159	0.134	0.117	0.138	0.126	0.094	0.117	0.170	0.163	10,473
Weighted average	0.188	0.123	0.102	0.085	0.070	0.069	0.058	0.056	0.058	0.100	0.101	278,443

and those are only for the last 5 years in those countries, it is not possible to use preceding interpregnancy intervals.

The analysis of infant and child mortality includes the following mortality rates: neonatal (deaths within 1st 30 days among all children born), postneonatal (deaths to children at ages 1 to 11 months among children surviving the neonatal period, infant (deaths to children at ages 0 to 11 months among all children born), child mortality (deaths to children at ages 1 to 4 years among children who survive to age 1 year) and under-five mortality (deaths to children under 5 years of age among all children born).

The mortality rates by length of preceding birth interval are shown in Tables 3—5. Under-five mortality in the 17 selected countries varies from 42 to 163 deaths per thousand births (Table 3). On average, children born after short intervals, under 18 months between births and 18 to 23 months between births, are respectively 3.0 and 1.9 times as likely to die before their fifth birthday as are children born after 36 to 59 months. In addition, those children born after intervals of 24 to 29

Table 4 Infant rates by duration of preceding birth interval, birth 60 to 179 months prior to survey

Survey	Preceding birth intervals									First birth	Total	*N*
	<18 months	18—23 months	24—29 months	30—35 months	36—41 months	42—47 months	48—53 months	54—59 months	60+ months			
Bangladesh (1996—1997)	0.180	0.115	0.088	0.072	0.068	0.073	0.070	0.050	0.056	0.122	0.098	13,343
Bolivia (1994)	0.165	0.118	0.089	0.075	0.063	0.044	0.043	0.032	0.054	0.069	0.089	11,094
Côte d'Ivoire (1994)	0.174	0.118	0.084	0.068	0.052	0.048	0.047	0.048	0.056	0.114	0.092	11,645
Egypt (1995)	0.174	0.096	0.065	0.052	0.041	0.034	0.036	0.043	0.044	0.082	0.082	25,407
Ghana (1993)	0.152	0.100	0.082	0.072	0.047	0.051	0.030	0.032	0.054	0.081	0.074	6178
Guatemala (1995)	0.134	0.071	0.058	0.050	0.045	0.043	0.038	0.040	0.043	0.068	0.066	17,290
India (1992—1993)	0.150	0.089	0.073	0.059	0.049	0.059	0.038	0.034	0.040	0.090	0.080	24,702
Indonesia (1994)	0.140	0.076	0.070	0.062	0.048	0.040	0.038	0.037	0.042	0.063	0.067	40,326
Kenya (1993)	0.119	0.066	0.049	0.055	0.050	0.044	0.034	0.040	0.043	0.070	0.063	11,248
Morocco (1995)	0.154	0.067	0.059	0.046	0.048	0.036	0.027	0.024	0.034	0.078	0.069	10,123
Nepal (1996)	0.197	0.135	0.106	0.080	0.068	0.058	0.037	0.053	0.042	0.117	0.104	13,174
Nigeria (1990)	0.169	0.099	0.084	0.080	0.056	0.074	0.064	0.054	0.036	0.093	0.090	13,681
Peru (1996)	0.131	0.077	0.054	0.048	0.034	0.037	0.036	0.037	0.036	0.047	0.059	32,327
Philippines (1993)	0.075	0.043	0.042	0.033	0.027	0.024	0.030	0.036	0.033	0.035	0.042	16,472
Tanzania (1996)	0.179	0.115	0.089	0.068	0.065	0.063	0.049	0.065	0.066	0.105	0.091	10,821
Uganda (1995)	0.143	0.097	0.070	0.063	0.053	0.064	0.041	0.034	0.051	0.101	0.084	10,139
Zambia (1996)	0.200	0.137	0.092	0.076	0.067	0.090	0.085	0.052	0.073	0.114	0.103	10,473
Weighted average	0.151	0.090	0.071	0.060	0.049	0.049	0.042	0.041	0.045	0.079	0.076	278,443

Table 5 Neonatal rates by duration of preceding birth interval, births 60 to 179 months prior to survey

Survey	Preceding birth intervals									First birth	Total	*N*
	<18 months	18–23 months	24–29 months	30–35 months	36–41 months	42–47 months	48–53 months	54–59 months	60+ months			
Bangladesh (1996–1997)	0.105	0.068	0.051	0.041	0.041	0.050	0.046	0.029	0.036	0.085	0.062	13,343
Bolivia (1994)	0.089	0.063	0.037	0.035	0.026	0.017	0.016	0.013	0.031	0.034	0.044	11,094
Côte d'Ivoire (1994)	0.097	0.063	0.046	0.032	0.028	0.027	0.031	0.021	0.027	0.064	0.050	11,645
Egypt (1995)	0.086	0.044	0.030	0.028	0.021	0.016	0.016	0.019	0.028	0.047	0.042	25,407
Ghana (1993)	0.107	0.064	0.055	0.040	0.022	0.022	0.016	0.022	0.034	0.055	0.046	6178
Guatemala (1995)	0.077	0.038	0.028	0.026	0.024	0.021	0.019	0.017	0.023	0.040	0.036	17,290
India (1992–1993)	0.090	0.044	0.040	0.033	0.026	0.033	0.018	0.026	0.028	0.060	0.047	24,702
Indonesia (1994)	0.065	0.034	0.033	0.026	0.021	0.017	0.017	0.016	0.023	0.033	0.032	40,326
Kenya (1993)	0.056	0.023	0.022	0.025	0.027	0.017	0.020	0.018	0.017	0.036	0.029	11,248
Morocco (1995)	0.084	0.031	0.024	0.023	0.022	0.023	0.011	0.009	0.023	0.045	0.036	10,123
Nepal (1996)	0.117	0.076	0.059	0.045	0.042	0.035	0.021	0.033	0.027	0.080	0.063	13,174
Nigeria (1990)	0.092	0.050	0.045	0.042	0.026	0.038	0.029	0.027	0.017	0.054	0.048	13,681
Peru (1996)	0.066	0.038	0.026	0.024	0.018	0.020	0.019	0.024	0.021	0.025	0.030	32,327
Philippines (1993)	0.031	0.018	0.018	0.017	0.012	0.013	0.012	0.020	0.019	0.021	0.020	16,472
Tanzania (1996)	0.086	0.051	0.037	0.030	0.028	0.024	0.019	0.020	0.019	0.049	0.040	10,821
Uganda (1995)	0.062	0.040	0.024	0.023	0.016	0.018	0.019	0.010	0.017	0.045	0.034	10,139
Zambia (1996)	0.086	0.046	0.030	0.027	0.025	0.032	0.020	0.016	0.026	0.044	0.038	10,473
Weighted Average	0.079	0.044	0.034	0.029	0.024	0.024	0.020	0.020	0.024	0.045	0.039	278,443

months and 30 to 35 months have a 60% and 30% greater chance of dying, respectively, than do children born after 36 to 59 months. For the countries studied, the increases in the risk of dying range from 124% to 381% for births occurring less than 18 months since the preceding birth, from 43% to 145% higher for the 18–23 months interval duration, from 18% to 100% higher for the 24 to 29 months interval duration, and from 5% to 60% higher for the 30 to 35 months interval duration.

Similar patterns of excess mortality by interval durations occur for infant mortality (Table 4) and neonatal mortality (Table 5). Compared with a preceding birth interval of 36 to 59 months, infant mortality is higher on average by 230%, 100%, 60%, and 30% for intervals less than 18 months, 18 to 23 months, 24 to 29 months, and 30 to 35 months, respectively. For neonatal mortality average of excess mortality is 260%, 200%, 60%, and 30% for intervals less than 18 months, 18 to 23 months, 24 to 29 months, and 30 to 35 months, respectively.

2.4.2. Nutritional status

Nutritional status was determined by anthropometric measurements on children under age 5 in Bangladesh, Guatemala, Kenya, Morocco, Nigeria, Peru, Tanzania, and Zambia. In India and Uganda, children under age 4 years were weighed and measured, and measurements were made on children under age 3 years in Bolivia, Côte d'Ivoire, Ghana, and Nepal. In 3 of the 17 surveys, Egypt, Indonesia, and the Philippines, anthropometry was not included. Children who were born in the month of interview were not analyzed. Table 6 presents the percent of children stunted, underweight, and wasted according to the duration of the preceding birth interval. The unweighted averages show an almost linear decline in stunting as birth interval increases (Kendall's τ_b=−0.78, p=.004). There is a lesser linear relationship between birth interval and underweight (τ_b=−0.67, p=.012), and basically no relationship with wasting (τ_b=+0.17, p=.532).

2.5. Multivariate results

2.5.1. Under-five mortality

Table 7 presents the adjusted odds ratios for under-five mortality by length of preceding birth interval for each survey. For this analysis, children born between 60 and 179 months prior to each survey interview are considered. Later born children are not used because they have not had 60 months of exposure to mortality. Children born earlier are excluded due to truncation of the data file.[8]

In all 17 surveys, the relationship between the preceding birth interval and under-five mortality is highly significant (p<0.001). For intervals less than 30 months, the adjusted odds ratios are always substantially higher than those of the reference group. For the interval 30–34 months, the adjusted odds ratios are substantially higher in 14 of the 17 surveys. The behavior of the adjusted relative odds

[8] Since the oldest respondents to the surveys are 49 years of age, information on births is increasingly limited to younger women as periods in the past are considered. For example, the data on births 180 months prior to the survey pertains to women up to the age of 34 years.

Table 6 Percentage of children stunted, underweight and wasted by duration of preceding birth interval

Stunting	Children's age range	Preceding birth intervals <18 months	18 to 23 months	24 to 29 months	30 to 35 months	36 to 41 months	42 to 47 months	48 to 53 months	54 to 59 months	60+ months	First birth	Total
Bangladesh	1 to 59 months	62.1%	52.3%	61.2%	52.7%	50.2%	52.6%	48.4%	48.3%	43.9%	42.7%	49.7%
Bolivia	1 to 35 months	28.4%	24.4%	29.4%	31.1%	24.2%	25.2%	21.2%	25.1%	17.7%	16.7%	23.7%
Côte d'Ivoire	1 to 35 months	21.7%	27.3%	24.1%	25.8%	23.0%	21.5%	18.5%	17.6%	16.5%	25.7%	23.3%
Ghana	1 to 35 months	27.7%	28.6%	30.4%	28.4%	18.9%	22.0%	19.1%	16.8%	13.8%	26.2%	23.4%
Guatemala	1 to 59 months	55.0%	52.4%	53.1%	52.9%	48.9%	42.0%	45.4%	36.9%	30.3%	36.2%	46.4%
India	1 to 47 months	38.9%	34.3%	35.2%	31.3%	34.7%	31.8%	32.7%	30.1%	25.4%	25.2%	31.1%
Kenya	1 to 59 months	29.8%	32.1%	34.9%	32.1%	27.5%	27.4%	30.2%	16.7%	23.4%	24.0%	29.1%
Morocco	1 to 59 months	24.9%	29.8%	30.1%	27.6%	24.6%	22.0%	19.9%	20.2%	16.6%	15.8%	23.6%
Nepal	1 to 35 months	52.7%	46.4%	49.5%	45.0%	49.6%	47.4%	47.9%	42.8%	46.3%	37.3%	45.4%
Nigeria	1 to 59 months	31.3%	40.8%	38.0%	36.2%	33.5%	35.6%	33.3%	27.9%	32.9%	33.3%	35.4%
Peru	1 to 59 months	29.5%	34.7%	36.7%	32.2%	30.7%	22.4%	26.0%	18.3%	12.8%	14.6%	23.9%
Tanzania	1 to 59 months	36.7%	44.3%	41.8%	41.4%	42.0%	37.4%	36.0%	38.4%	35.1%	37.4%	39.6%
Uganda	1 to 47 months	37.8%	37.6%	36.8%	34.2%	34.6%	30.2%	42.8%	36.8%	28.7%	33.4%	35.2%
Zambia	1 to 59 months	44.0%	38.6%	40.2%	41.5%	37.3%	37.0%	36.0%	38.6%	33.8%	38.7%	39.0%
Average		37.2%	37.4%	38.7%	36.6%	34.3%	32.5%	32.7%	29.6%	26.9%	29.1%	33.5%

Underweight	Children's age range	Preceding birth intervals <18 months	18 to 23 months	24 to 29 months	30 to 35 months	36 to 41 months	42 to 47 months	48 to 53 months	54 to 59 months	60+ months	First births	Total
Bangladesh	1 to 59 months	60.8%	53.5%	58.9%	56.3%	52.2%	51.3%	53.5%	51.0%	45.8%	45.0%	51.1%
Bolivia	1 to 35 months	17.8%	12.8%	19.4%	13.4%	13.3%	15.6%	10.9%	12.3%	7.4%	9.8%	13.2%
Côte d'Ivoire	1 to 35 months	18.3%	24.4%	22.4%	26.7%	25.7%	19.9%	18.5%	17.1%	16.9%	23.2%	22.6%
Ghana	1 to 35 months	19.1%	34.5%	31.3%	29.6%	21.7%	24.7%	24.4%	22.8%	20.9%	21.8%	25.0%
Guatemala	1 to 59 months	34.0%	26.6%	26.5%	28.9%	24.8%	26.0%	24.3%	21.8%	17.6%	18.6%	24.8%
India	1 to 47 months	46.9%	47.5%	51.4%	47.1%	49.2%	48.3%	50.0%	45.5%	39.6%	41.6%	46.1%
Kenya	1 to 59 months	23.6%	23.9%	23.1%	21.5%	19.0%	19.0%	21.9%	13.5%	13.7%	14.7%	19.8%
Morocco	1 to 59 months	11.9%	10.1%	12.3%	10.6%	10.4%	7.3%	7.7%	7.0%	6.8%	6.1%	9.2%
Nepal	1 to 35 months	48.4%	45.5%	48.7%	44.8%	48.2%	41.3%	45.2%	51.3%	44.4%	36.0%	44.0%
Nigeria	1 to 59 months	22.6%	31.6%	32.6%	28.7%	30.8%	32.3%	25.7%	23.0%	26.4%	28.4%	29.3%
Peru	1 to 59 months	8.9%	9.9%	11.6%	9.3%	10.6%	7.2%	8.7%	4.7%	3.5%	4.3%	7.2%
Tanzania	1 to 59 months	26.1%	33.2%	27.7%	29.0%	30.0%	25.3%	28.8%	29.9%	5.7%	25.5%	27.9%

(continued on next page)

Table 6 (*continued*)

Underweight	Children's age range	Preceding birth intervals									First births	Total
		<18 months	18 to 23 months	24 to 29 months	30 to 35 months	36 to 41 months	42 to 47 months	48 to 53 months	54 to 59 months	60+ months		
Uganda	1 to 47 months	22.7%	25.7%	22.4%	23.1%	26.2%	22.9%	32.0%	24.6%	17.2%	22.0%	23.4%
Zambia	1 to 59 months	24.6%	21.5%	21.2%	21.2%	25.3%	18.9%	21.8%	20.9%	21.0%	20.9%	21.6%
Average		27.6%	28.6%	29.3%	27.9%	27.7%	25.7%	26.7%	24.7%	21.9%	22.7%	26.1%
Wasting	**Children's age range**	**Preceding birth intervals**									**First births**	**Total**
		<18 months	18 to 23 months	24 to 29 months	30 to 35 months	36 to 41 months	42 to 47 months	48 to 53 months	54 to 59 months	60+ months		
Bangladesh	1 to 59 months	16.7%	14.7%	13.5%	19.2%	16.8%	15.7%	17.9%	15.8%	16.7%	15.1%	16.0%
Bolivia	1 to 35 months	3.6%	3.3%	4.0%	3.9%	3.7%	5.7%	5.2%	1.3%	2.2%	3.9%	3.7%
Côte d'Ivoire	1 to 35 months	3.6%	6.3%	8.7%	8.7%	10.9%	6.3%	8.5%	7.1%	8.7%	8.1%	8.2%
Ghana	1 to 35 months	4.3%	13.4%	12.9%	12.4%	14.3%	15.1%	13.0%	7.9%	11.3%	7.2%	11.4%
Guatemala	1 to 59 months	3.6%	2.5%	2.4%	3.4%	4.1%	1.9%	1.0%	3.6%	4.1%	3.2%	3.0%
India	1 to 47 months	9.5%	10.7%	10.7%	10.4%	10.0%	12.4%	14.1%	10.9%	9.3%	8.8%	10.2%
Kenya	1 to 59 months	6.8%	7.3%	6.2%	5.8%	4.7%	5.5%	3.4%	6.9%	5.1%	3.3%	5.4%
Morocco	1 to 59 months	3.1%	1.8%	2.8%	2.2%	2.4%	0.4%	1.8%	0.8%	2.7%	1.9%	2.2%
Nepal	1 to 35 months	12.7%	12.5%	10.7%	9.8%	11.7%	10.2%	13.9%	17.0%	10.3%	7.6%	10.6%
Nigeria	1 to 59 months	6.3%	8.6%	7.9%	7.5%	10.1%	16.5%	9.7%	3.6%	7.6%	9.8%	8.8%
Peru	1 to 59 months	0.9%	1.1%	1.3%	0.9%	1.1%	2.2%	1.9%	1.3%	0.9%	0.7%	1.0%
Tanzania	1 to 59 months	4.6%	6.5%	4.9%	6.6%	7.5%	7.4%	7.2%	9.1%	5.9%	7.2%	6.5%
Uganda	1 to 47 months	3.2%	5.4%	3.5%	6.7%	6.2%	5.8%	3.8%	8.3%	4.3%	4.3%	4.9%
Zambia	1 to 59 months	4.9%	3.1%	3.7%	4.0%	4.6%	2.7%	2.3%	3.0%	5.6%	3.6%	3.8%
Average		6.0%	6.9%	6.7%	7.3%	7.7%	7.7%	7.4%	6.9%	6.8%	6.0%	6.8%

for periods longer than the reference is somewhat variable but mostly lower than that of the reference period. Fig. 1 shows the weighted average[9] effect of preceding birth interval on under-five mortality. The risk of mortality trends downwards with increasing birth interval, rapidly until 36—47 months and then more slowly with longer intervals.

[9] The weight for each regression coefficient is the inverse of the squared standard error divided by the sum of the inverses of the squared standard errors. The average of the coefficients is then exponentiated to get the average of the adjusted odds ratio. The standard error for the weighted average coefficient is the square root of the sum of the squared coefficients weighted by the squared number of cases divided by the sum of the squared number of cases.

2.5.2. Infant mortality

The analysis of infant mortality is based on births that occurred 12 to 59 months prior to the survey to ensure full exposure to mortality. Table 8 presents the results of the multivariate analysis. In addition to the control variables included in the analysis of under-five years mortality, the wantedness of the birth (wanted at the time of conception, wanted later, did not want any more children) is used. Additionally, in the surveys with reproductive calendar data whether or not the birth was the result of a contraceptive failure is included.

All 17 countries have significant results for the relationship between preceding birth interval and infant mortality. For intervals less than 24 months, all countries have adjusted relative odds ratios of

Table 7 Adjusted odds ratios of under 5 years mortality for preceding birth intervals

Survey	Significance	Preceding birth intervals									First birth	N
		<18 months	18–23 months	24–29 months	30–35 months	36–41 months	42–47 months	48–53 months	54–59 months	60+ months		
Reference												
Bangladesh (1996–1997)	***	2.72	1.77	1.32	1.13	1	1.07	1.14	0.57	0.70	1.97	13,343
Bolivia(1994)	***	2.99	2.23	1.77	1.36	1	0.68	0.80	0.54	0.90	1.60	11,094
Côte d'Ivoire (1994)	***	2.73	2.05	1.65	1.46	1	1.16	0.83	0.68	1.03	2.26	11,845
Egypt (1995)	***	5.56	3.02	1.99	1.65	1	1.00	0.90	1.42	1.25	3.15	25,427
Ghana (1993)	***	2.41	1.86	1.92	1.34	1	1.02	0.98	0.67	0.86	1.83	6178
Guatemala (1995)	***	3.74	2.06	1.68	1.29	1	0.97	0.91	1.13	0.91	2.11	17,290
India (1992–1993)	***	2.73	1.58	1.34	1.13	1	0.88	0.54	0.57	0.53	1.55	24,702
Indonesia (1994)	***	3.06	1.64	1.57	1.38	1	0.96	0.68	0.75	0.84	1.76	40,584
Kenya (1993)	***	2.31	1.44	1.23	1.03	1	1.07	0.56	0.58	0.68	1.49	11,248
Morocco (1995)	***	3.02	1.41	1.23	0.95	1	0.66	0.65	0.37	0.68	1.59	10,123
Nepal (1996)	***	3.11	2.16	1.68	1.24	1	0.98	0.65	0.48	0.45	1.59	13,174
Nigeria (1990)	***	2.23	1.46	1.45	1.34	1	1.32	0.74	0.67	0.49	1.61	13,681
Peru (1996)	***	4.32	2.85	1.88	1.46	1	0.95	1.19	1.23	1.39	2.08	32,377
Philippines (1993)	***	2.44	1.49	1.32	1.02	1	1.06	0.77	1.05	0.85	1.65	16,488
Tanzania (1996)	***	2.64	2.17	1.66	1.12	1	1.14	0.70	1.26	0.95	1.69	10,840
Uganda (1995)	***	2.38	1.83	1.48	1.20	1	1.19	0.64	0.68	0.66	1.73	10,153
Zambia (1996)	***	3.01	2.01	1.47	1.14	1	1.22	1.15	0.92	0.88	1.45	10,497
Average	***	3.02	1.91	1.56	1.26	1	1.02	0.82	0.82	0.83	1.79	279,044

Level of significance: ***<.001.

Adjusted for: Sex of child, birth order, multiplicity of birth, mother's age at birth, survival of preceding child by date of conception, prenatal care provider, timing of first prenatal care visit (if any), number of prenatal tetanus toxoid vaccinations, delivery attendant, urban—rural residence, mother's education, and index of household wealth.

Average is exponentiated weighted average of coefficients with the inverse of the squared standard error as the weight.

1.20 or higher. For the birth intervals 24—29 and 30—35 months, the increase in mortality is somewhat mixed, with two and three countries having adjusted odds ratios substantially below one in each interval, respectively. However, 15 countries in the 24—29 interval and 11 in the 30—35 interval have odds ratios substantially higher than one. The weighted average of the odds ratios by preceding birth interval show that the lowest odds ratios occur in the 36 to 59 month period (Fig. 2).

2.5.3. Neonatal mortality

The results for neonatal mortality are shown in Table 9. Eleven of the 17 countries have highly significant ($p<0.001$) results, four are significant at the 1% level, one (Indonesia) is significant at the 5%

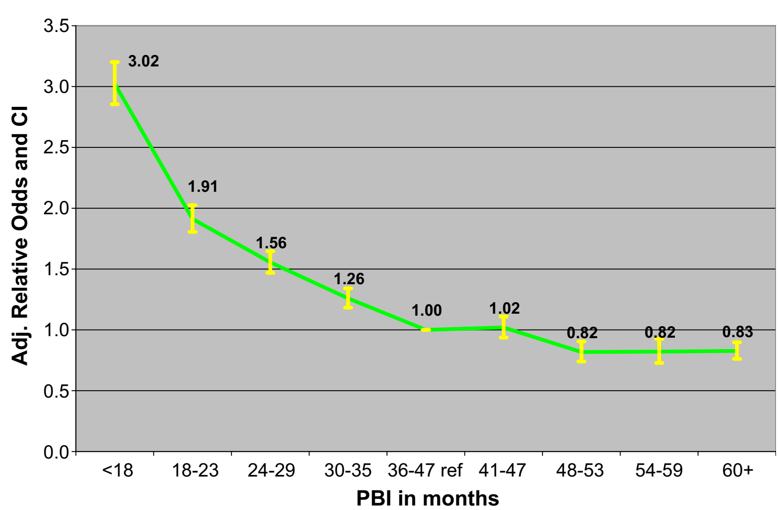

Figure 1 Under-five mortality by birth interval (17 DHS surveys).

Table 8 Adjusted odds ratios of infant mortality for preceding birth intervals

Survey	Significance	Preceding birth intervals									First birth	N
		<18 months	18–23 months	24–29 months	30–35 months	36–41 months	42–47 months	48–53 months	54–59 months	60+ months		
Reference												
Bangladesh (1996–1997)	***	2.63	1.52	1.63	0.99	1	0.91	0.72	0.94	0.80	2.14	4948
Bolivia(1994)	***	2.07	1.52	0.84	1.03	1	0.34	0.71	0.72	1.22	0.98	4928
Côte d'Ivoire (1994)	***	4.12	2.67	1.67	1.37	1	0.41	1.11	1.48	1.58	3.42	5429
Egypt (1995)	***	5.01	2.62	1.77	1.27	1	0.96	1.14	1.18	1.16	1.83	9744
Ghana (1993)	***	7.31	3.18	2.55	2.05	1	1.99	0.85	0.75	1.35	2.19	2973
Guatemala (1995)	***	2.37	1.33	1.33	1.16	1	0.91	0.72	0.56	1.13	2.01	7812
India (1992–1993)	***	3.44	2.25	1.59	1.41	1	1.80	0.92	0.84	1.17	2.69	9433
Indonesia (1994)	***	1.87	1.57	1.23	1.14	1	0.89	1.09	0.74	0.93	1.28	14,614
Kenya (1993)	***	2.05	1.20	0.59	1.36	1	0.68	0.43	1.18	0.61	1.79	4869
Morocco (1995)	***	4.89	1.41	1.64	0.78	1	1.54	0.90	0.37	0.75	1.44	4197
Nepal (1996)	***	3.24	1.80	1.63	0.89	1	0.74	0.34	0.74	1.03	2.12	5876
Nigeria (1990)	***	2.19	1.97	1.33	1.67	1	0.82	1.02	0.75	0.54	1.53	6198
Peru (1996)	***	3.80	2.16	1.78	1.71	1	1.34	1.06	1.47	1.41	1.37	14,220
Philippines (1993)	*	2.73	1.90	1.36	1.18	1	0.67	1.27	2.06	1.73	1.75	7344
Tanzania (1996)	***	1.96	1.53	1.37	0.80	1	0.79	0.74	1.11	0.75	1.63	5269
Uganda (1995)	***	2.91	1.82	1.17	1.25	1	1.06	0.73	0.65	1.55	2.37	5644
Zambia (1996)	***	1.95	2.15	1.38	1.03		1.21	1.02	0.80	1.01	1.87	5729
Average	***	2.84	1.85	1.40	1.20	1	0.98	0.90	0.95	1.05	1.81	119,227

Level of significance: ***<.001, *<.05.

Adjusted for: Sex of child, birth order, multiplicity of birth, mother's age at birth, survival of preceding child by date of conception, prenatal care provider, timing of first prenatal care visit (if any), number of prenatal tetanus toxoid vaccinations, delivery attendant, urban–rural residence, mother's education, index of household wealth, wantedness of child and whether birth was result of a contraceptive failure.

Average is exponentiated weighted average of coefficients with the inverse of the squared standard error as the weight.

level, and for one (Philippines) the result is not significant at the 5% level. The neonatal results for all but Kenya generally follow the patterns shown for under-five and infant mortality. The weighted averages of the adjusted odds ratios decline with increasing birth interval length (Fig. 3). They are lowest for birth intervals 48 to 59 months, somewhat below that for 36 to 47 month intervals. The odds ratio increases again somewhat for the open interval of 60 months or longer.

2.5.4. Breastfeeding

The duration of breastfeeding of children can act as a possible confounding factor for the relationship between preceding birth interval and young child mortality. The confounding comes about

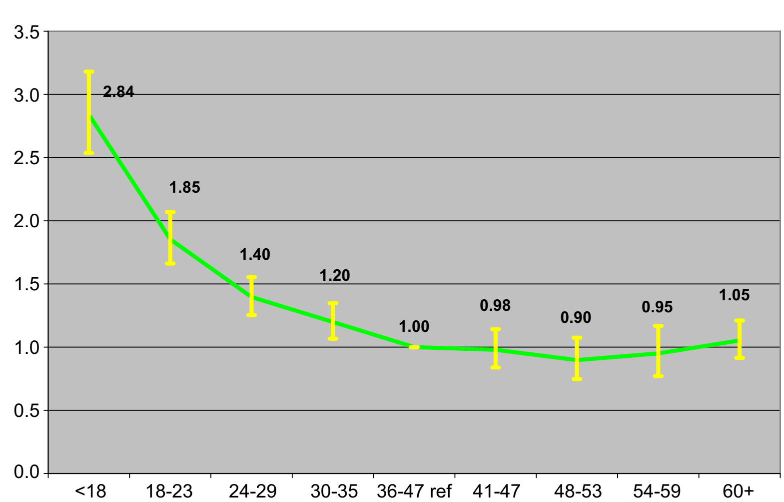

Figure 2 Infant mortality by birth interval (17 DHS surveys).

Table 9 Adjusted odds ratios of neonatal mortality for preceding birth intervals

Survey	Significance	Preceding birth intervals									First birth	*N*
		<18 months	18–23 months	24–29 months	30–35 months	36–41 months	42–47 months	48–53 months	54–59 months	60+ months		
Reference												
Bangladesh (1996–1997)	***	1.90	1.47	1.35	1.02	1	1.08	0.68	0.87	1.23	2.60	6103
Bolivia(1994)	***	2.34	1.76	0.79	0.92	1	0.37	0.55	0.60	1.22	0.89	6132
Côte d'Ivoire (1994)	***	3.39	1.99	1.29	1.18	1	0.77	1.02	1.10	0.81	3.55	6721
Egypt (1995)	***	4.05	2.24	1.38	1.40	1	0.80	1.05	1.05	1.58	2.63	12,003
Ghana (1993)	***	11.86	3.13	2.61	2.61	1	1.04	0.87	0.88	1.34	3.04	3737
Guatemala (1995)	**	2.19	1.16	1.11	1.06		0.99	0.60	0.54	1.09	1.51	9801
India (1992–1993)	***	3.14	1.94	1.61	1.55	1	1.82	0.99	1.01	1.60	3.03	11,937
Indonesia (1994)	*	1.65	1.15	1.22	1.06	1	0.55	1.02	0.80	1.11	1.53	18,022
Kenya (1993)	**	0.74	0.82	0.56	0.87	1	0.39	0.48	0.39	0.35	2.08	6014
Morocco (1995)	***	5.65	1.28	1.55	1.31	1	2.20	0.94	0.36	1.61	1.89	5130
Nepal (1996)	***	2.30	1.84	1.34	1.08	1	1.04	0.39	1.02	0.86	2.36	7265
Nigeria (1990)	***	3.39	2.38	1.56	1.64	1	1.57	1.54	1.35	0.51	2.21	7816
Peru (1996)	***	3.83	2.34	1.78	1.91	1	1.62	1.29	1.59	1.48	1.64	17,357
Philippines (1993)	ns	1.58	1.11	0.84	0.78	1	0.44	1.29	0.76	0.93	1.36	9080
Tanzania (1996)	**	2.14	1.38	1.24	1.05	1	0.65	0.66	0.90	0.45	2.11	6622
Uganda (1995)	***	4.52	2.49	0.92	1.24	1	1.05	1.21	0.84	1.39	3.43	7060
Zambia (1996)	**	3.38	1.54	1.46	0.94		1.32	0.85	0.90	1.14	1.94	7117
Average	***	2.72	1.67	1.27	1.21	1	1.03	0.92	0.93	1.08	2.09	147,917

Level of significance: ***<.001, **<.01, *<.05, ns>.05.

Adjusted for: Sex of child, birth order, multiplicity of birth, mother's age at birth, survival of preceding child by date of conception, prenatal care provider, timing of first prenatal care visit (if any), number of prenatal tetanus toxoid vaccinations, delivery attendant, urban–rural residence, mother's education, index of household wealth, wantedness of child and whether birth was result of a contraceptive failure.

Average is exponentiated weighted average of coefficients with the inverse of the squared standard error as the weight.

because short durations of breastfeeding of the preceding child, especially exclusive breastfeeding, result in short durations of postpartum amenorrhea and therefore shortened birth intervals. If a mother also breastfeeds her next child for a short time, it may be at increased risk therefore confounding the relationship between birth intervals and mortality.

Table 10 presents the results of analyses including breastfeeding of the index child, according to exposure age. Because the death of a child ends breastfeeding, the analysis has to be handled in a special way in order to handle the reciprocal relationship between mortality and breastfeeding. In this table, five ages of mortality are considered: 2–3 months, 4–6 months, 7–8 months, 9–

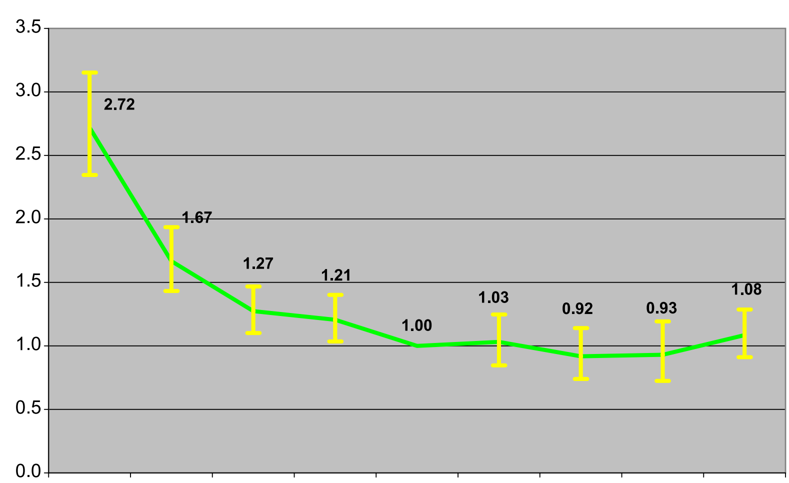

Figure 3 Neonatal mortality by birth interval (17 DHS surveys).

Table 10 Adjusted relative odds of dying by preceding birth interval (PBI) with and without control for breastfeeding duration (BF) (pooled data from 17 countries)

PBI	2–3 months[a]			4–6 months[b]			7–8 months[c]			9–12 months[d]			13–24 months[e]		
	Without BF	With BF	Relative change (%)	Without BF	With BF	Relative change (%)	Without BF	With BF	Relative change (%)	Without BF	With BF	Relative change (%)	Without BF	With BF	Relative change (%)
PBI															
<18	2.49	2.37	4.9	2.41	2.30	4.5	2.86	2.62	8.4	2.13	2.01	5.5	2.08	2.07	0.4
18–23	1.41	1.40	0.7	1.74	1.73	0.9	1.73	1.68	2.8	1.49	1.46	2.6	1.69	1.69	0.2
24–29	1.29	1.30	0.1	1.25	1.25	0.0	1.65	1.65	0.6	1.15	1.14	1.1	1.50	1.50	0.1
30–35	0.94	0.94	0.5	1.09	1.09	0.2	1.43	1.42	0.3	1.09	1.08	0.8	1.16	1.16	0.0
36–41 (ref.)	1	1		1	1		1	1		1	1		1	1	
42–47	0.91	0.90	0.7	0.94	0.93	0.8	1.20	1.18	1.0	0.98	0.96	1.2	0.85	0.85	0.1
48–53	0.89	0.90	0.5	0.85	0.85	0.4	1.20	1.19	1.1	0.76	0.75	1.2	0.92	0.92	0.1
54–59	1.14	1.13	0.4	1.05	1.04	1.3	1.30	1.28	1.6	0.88	0.87	1.0	0.62	0.62	0.1
60+	1.02	1.00	2.0	0.91	0.88	2.3	1.47	1.43	2.3	1.15	1.13	1.4	0.80	0.80	0.1
First birth	1.59	1.53	4.3	1.45	1.40	3.7	1.70	1.60	6.0	1.54	1.49	3.1	1.32	1.31	0.2
BF															
Yes[f]	ni	4.03		ni	3.08		ni	3.18		ni	2.29		ni	1.18	
No (ref.)	ni	1		ni	1		ni	1		ni	1		ni	1	
N	117,011			109,644			104,303			95,191			270,888		

ni: not included.
[a] Children born 4 to 59 months prior to survey excluding those with preceding deaths.
[b] Children born 7 to 59 months prior to survey excluding those with preceding deaths.
[c] Children born 9 to 59 months prior to survey excluding those with preceding deaths.
[d] Children born 13 to 59 months prior to survey excluding those with preceding deaths.
[e] Children born 25 to 59 months prior to survey excluding those with preceding deaths.
[f] Stopped breastfeeding prior to beginning of exposure interval (age).

12 months, and 13–24 months. The effect of breastfeeding is examined by determining whether or not the child had stopped breastfeeding by the beginning of the age interval. This procedure eliminates the effect of the child's death on the duration of breastfeeding. Because of the short age intervals and the concomitant reduced number of deaths, the data from all 17 countries have been pooled in these analyses. Only children without the death of the preceding child are included in order to control spurious effects. The results from Table 10 show that there is a minimal effect of additionally controlling for breastfeeding duration of the index child. The greatest change is a reduction of 0.12 in the adjusted odds ratio for births with a preceding birth interval of less than 18 months. In no other interval does the average change in the odds ratios reach 0.1. On the other

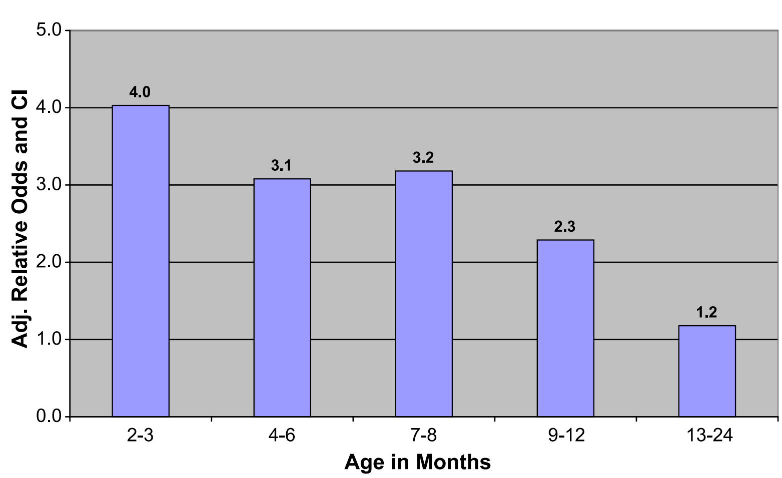

Figure 4 Mortality in age interval by whether stopped breastfeeding.

Table 11 Adjusted odds ratios of stunting for preceding birth intervals

Survey	Significance	Preceding birth intervals									First birth	*N*
		<18 months	18—23 months	24—29 months	30—35 months	36—41 months	42—47 months	48—53 months	54—59 months	60+ months		
Reference												
Bangladesh (1996—1997)	***	1.48	1.11	1.44	1.10	1	1.03	1.01	0.85	0.83	0.83	5198
Bolivia(1994)	ns	1.77	1.31	1.50	1.39	1	1.12	0.93	0.98	1.00	1.17	5513
Côte d'Ivoire (1994)	ns	0.90	1.22	1.14	1.02	1	1.03	0.86	0.71	0.88	1.06	5863
Egypt (1995)	na											na
Ghana (1993)	ns	1.41	1.50	1.73	1.50	1	1.67	1.70	1.09	0.87	1.96	3347
Guatemala (1995)	***	1.83	1.44	1.33	1.36	1	0.94	0.97	0.95	0.83	1.07	9015
India (1992—1993)	*	1.18	1.16	1.05	0.90	1	0.89	0.88	1.01	0.82	0.92	8589
Indonesia (1994)	na											na
Kenya (1993)	**	1.14	1.18	1.27	1.24	1	1.01	1.04	0.61	0.77	1.01	5391
Morocco (1995)	ns	1.31	0.74	1.22	0.88	1	0.14	0.82	0.33	1.23	0.76	4642
Nepal (1996)	ns	1.27	0.89	0.93	0.91	1	1.02	0.91	0.75	0.94	0.79	6509
Nigeria (1990)	ns	0.86	1.17	1.04	1.07	1	1.13	0.95	0.81	0.95	0.92	6533
Peru (1996)	***	1.22	1.27	1.27	1.12	1	0.75	1.00	0.71	0.70	0.77	16,059
Philippines (1993)	na											na
Tanzania (1996)	ns	0.79	1.06	1.02	0.98	1	0.85	0.74	0.97	0.80	1.06	5684
Uganda (1995)	ns	1.07	1.09	1.04	0.99	1	0.81	1.17	0.99	0.77	1.06	6121
Zambia (1996)	*	1.34	1.08	1.11	1.20	1	0.92	0.83	0.97	0.84	1.24	5912
Average	***	1.21	1.18	1.17	1.10	1	0.94	0.95	0.86	0.85	1.01	94,3 76

Level of significance: ***<.001, **<.01, *<.05, ns .05.

Adjusted for: Sex of child, birth order, mother's age at birth, survival of preceding child by date of conception, prenatal care provider, timing of first prenatal care visit (if any), number of prenatal tetanus toxoid vaccinations, delivery attendant, urban—rural residence, mother's education, wantedness of pregnancy, type of infant feeding, drinking water supply, type of toilet, whether household has a refrigerator, and index of household wealth.

Average is exponentiated weighted average of coefficients with the inverse of the squared standard error as the weight.

Table 12 Adjusted odds ratios of underweight for preceding birth intervals

Survey	Significance	Preceding birth intervals									First birth	*N*
		<18 months	18—23 months	24—29 months	30—35 months	36—41 months	42—47 months	48—53 months	54—59 months	60+ months		
Reference												
Bangladesh (1996—1997)	ns	1.35	1.08	1.21	1.17	1	0.89	1.18	0.92	0.89	0.96	5198
Bolivia(1994)	***	2.25	1.18	1.78	1.18	1	1.44	0.90	0.95	0.83	0.89	3218
Côte d'Ivoire (1994)	ns	0.68	0.95	0.91	1.06	1	0.73	0.75	0.68	0.72	1.08	5863
Egypt (1995)	na											na
Ghana (1993)	ns	0.72	2.01	1.58	1.40		1.54	1.79	1.33	1.24	1.33	3347
Guatemala (1995)	***	1.90	1.29	1.16	1.31	1	1.23	0.96	1.31	0.88	1.03	9015
India (1992—1993)	*	1.14	1.16	1.22	0.98	1	0.96	0.99	1.11	0.85	1.00	10,623
Indonesia (1994)	na											na
Kenya (1993)	**	1.27	1.29	1.30	1.23	1	1.08	1.10	0.80	0.69	0.96	5391
Morocco (1995)	ns	1.19	0.91	1.07	0.94		0.65	0.75	0.75	0.82	0.67	4642
Nepal (1996)	ns	1.13	0.87	0.92	0.89	1	0.73	0.89	0.99	0.81	0.76	6509
Nigeria (1990)	*	0.78	1.19	1.19	1.03	1	1.14	0.90	0.91	0.87	1.03	6533
Peru (1996)	***	1.12	1.05	1.02	0.82	1	0.68	0.87	0.61	0.62	0.80	16,059
Philippines (1993)	na											na
Tanzania (1996)	ns	0.84	1.13	0.98	0.95	1	0.77	0.86	1.16	0.93	1.11	5684
Uganda (1995)	ns	0.86	1.02	0.86	0.78	1	0.85	1.09	0.93	0.64	0.90	6121
Zambia (1996)	ns	0.93	0.89	0.81	0.84	1	0.78	0.83	0.75	0.82	0.93	5912
Average	***	1.14	1.11	1.08	1.01	1	0.92	0.96	0.95	0.82	0.96	94,115

Level of significance: ***<.001, **<.01, *<.05, ns ≥.05.

Adjusted for: Sex of child, birth order, mother's age at birth, survival of preceding child by date of conception, prenatal care provider, timing of first prenatal care visit (if any), number of prenatal tetanus toxoid vaccinations, delivery attendant, urban—rural residence, mother's education, Wantedness of pregnancy, type of infant feeding, drinking water supply, type of toilet, whether household has a refrigerator, and index of household wealth.

Average is exponentiated weighted average of coefficients with the inverse of the squared standard error as the weight.

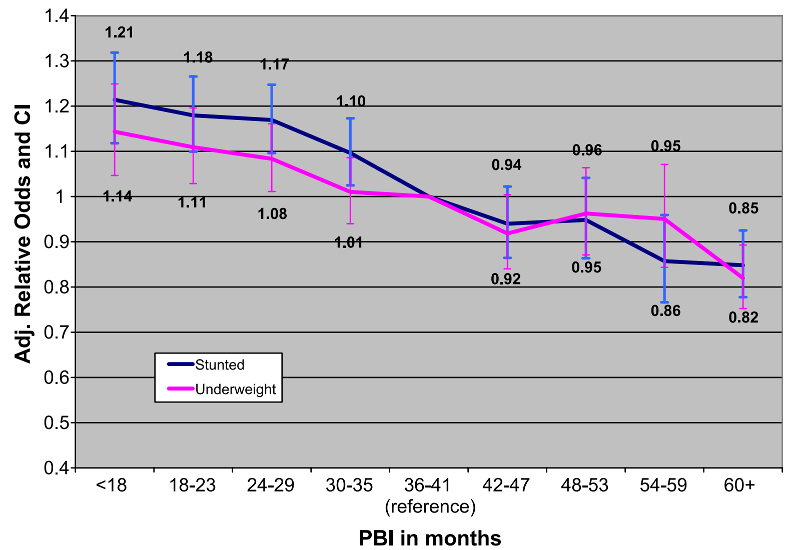

Figure 5 Child malnutrition by birth interval.

hand, the table does show the very large effect that stopping breastfeeding has on mortality. Fig. 4 shows that these effects decline with increasing age of the child.

2.5.5. Nutritional status

Logistic regressions for each country examined the effect of preceding birth interval on the percent of children stunted, wasted, and underweight. To control for potentially confounding factors the following variables were included in the regressions: child's age, sex, and birth order, mother's age at birth, and education, area of residence, prenatal care provider, timing of first prenatal care visit, number of prenatal tetanus toxoid vaccinations, formation of the birth attendant, wantedness of the pregnancy, type of infant feeding received the 24 h before interview, source of drinking water, type of toilet facility in the household, an index of household wealth, and whether or not the household has a refrigerator. The results of the analyses are shown in Tables 11 and 12.

Only 14 of the country surveys collected information on height and weight of children. In 6 countries, the relationship between preceding birth interval and stunting is significant. For underweight, significant results were found in 5 of the 14 countries. No significant results were found for wasting.

The weighted average odds ratios based on the results of the multivariate analyses in all 14 countries are shown in Fig. 5 for both stunting and underweight. It is clear that undernutrition declines substantially with longer intervals. Indeed, children born after an interval of less than 18

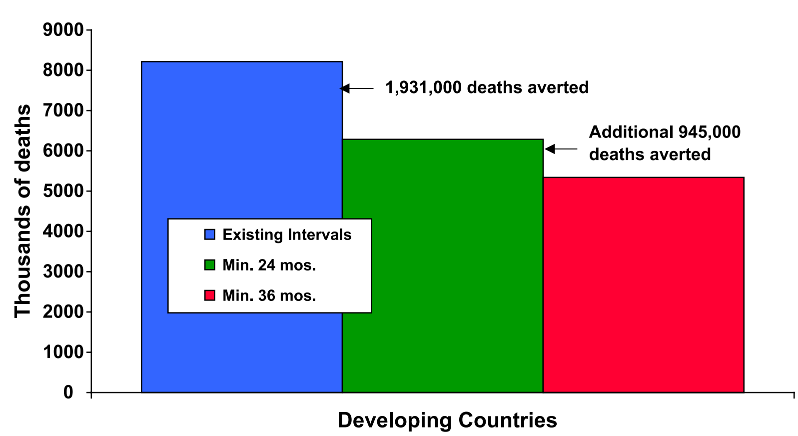

Figure 6 Annual number of under-five deaths with existing birth intervals and minimum intervals of 24 and 36 months (developing countries).

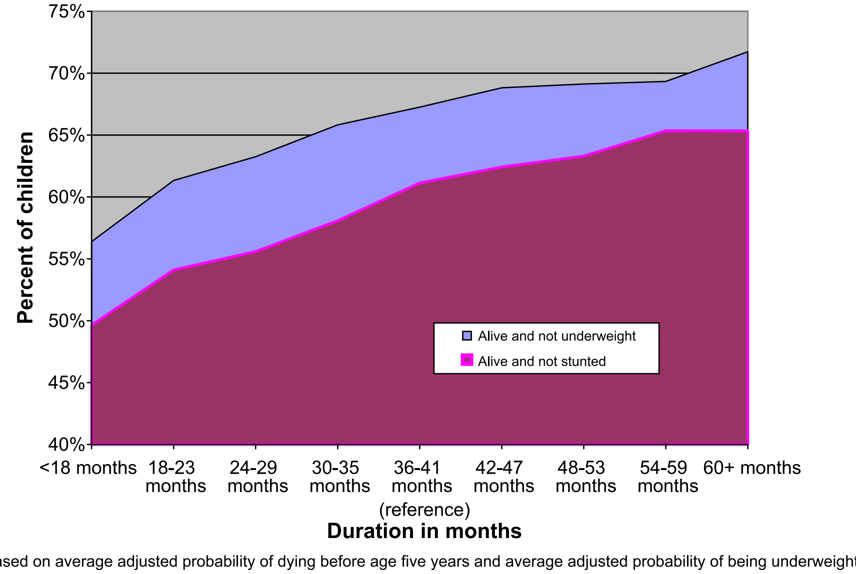

Figure 7 Percent of children alive and well nourished by duration of preceding birth interval.

months are 43% more likely to be stunted and 40% more likely to be underweight than children born after an interval of at least 60 months, based on the averaged odds ratios.

3. Discussion

3.1. Survival of children through the neonatal, infant, and under-five periods

Previous studies have well established that there is an important effect of the length of the preceding birth interval on the survival chances of a child through the neonatal, infant, and under five years periods of life. Some of the studies have given indications that the relationship is not linear with interval length, so that there may be an optimal period of birth spacing. The current study uses finer groupings of birth interval length than any of the previous studies. For neonatal mortality, the adjusted odds ratios indicate that risk of dying decreases with increasing birth interval lengths up to 36 months at which point the risk plateaus. There is some indication, although not significant, that the risk of neonatal mortality may rise for birth intervals of 5 and more years. The results for infant mortality are similar to those of neonatal mortality. For the risk of dying under age 5 years, the adjusted odds ratios indicate that the longer the birth interval, the lower the risk, even for intervals of 48 or more months.

Previous recommendations to women have been to avoid having birth sooner than 24 months apart. While the excess risk of mortality is highest for very short birth intervals (less than 18 months), there are relatively few children born with such intervals (16%). Combining both the increased risk of birth earlier than 36 months with the great number of birth with such intervals results substantial declines in mortality by avoiding intervals of 24 to 35 months. A calculation of the number of under-five deaths that could be averted by avoiding birth intervals under 24 months and the additional amount of deaths averted by avoiding birth intervals of 24 to 35 months is shown in Fig. 6. For the year 2003, if women in developing countries (excluding China) would not have had any births at intervals less than 24 months; they could have averted almost 2 million deaths in that year to children under age 5 years. An additional almost 1 million deaths in that year would have been averted if mothers had spaced at least 36 months between births. The deaths that would have been averted account for about 35% of all deaths to children less than 5 years of age in 2003.

3.2. Nutritional status

While the relationship between chronic and general malnutrition measured by the percent of children stunted and underweight, respectively, is not significant in the majority of the surveys with anthropometric data, there is a clear pattern of greater undernutrition with shorter birth intervals for the average of all the findings. It is beyond the scope of this paper to investigate the reasons that some data sets show significant results and others do not. However, the size of the sample of children does not appear to be the principal reason for this variation in significance.

For the surveys where significant results have been established, children face a double whammy to a healthy life from short preceding birth intervals: the risk of dying and the risk of being malnourished. An illustration of the effects of this double whammy is given in Fig. 7. In this figure the percentage of children who both survive to age 5 years and who are not underweight has been calculated from the averages of the adjusted odds ratios of under-five mortality and from the percent of children who are underweight. The steady increase in the percent both alive and not underweight underscores the large beneficial impact that additional waiting time to have another child can have on those children.

This paper has examined the impact of children at one end of the birth interval, those that follow the interval. The benefits to children at the other end, those that begin the interval, of birth spacing need to be examined in further studies. However, from a review of the literature, it is expected that these additional benefits of birth spacing are likely to accrue. Physicians and family planning programs should be made aware of these benefits and counsel their patients accordingly.

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