THE USE OF CONDITIONAL PROBABILITIES IN CHILD MORTALITY ESTIMATION

Alejandro Aguirre*
CEDDU, El Colegio de México, A.C.

(Received 14 june 2001, accepted 6 september 2002)

Abstract

The probabilities of death of relatives are not independent, as usually assumed. With information of birth histories from the World Fertility Survey it was found that exists stochastic dependence between the probabilities of death of succesive sibling. This result was used to develop an adjustment for an indirect technique for child mortality estimation: the Preceding Birth Technique.

Resumen

Las probalilidades de muerte de parientes no son independientes, como suele suponerse. Con información de historias de embarazos de la Encuesta Mundial de Fecundidad se encontró que existe dependencia estocástica entre las probabilidades de muerte de hermanos sucesivos. Esto sirvió para desarrollar un ajuste para una técnica indirecta de estimación de la mortalidad de la niñez. La Técnica del Hijo Previo.

JEL classification: C81, J13
Keywords: Conditional probabilities, Child mortality, Preceding Birth Technique

* Centro de Estudios Demográficos y de Desarrollo Urbano. El Colegio de México. Camino al Ajusco 20 C. P. 10740, México., D.F. Telephone (52). E-mail:aguirre@colmex.mx

The author is very grateful to the anonymous referees for their comments.

1. Introduction

When no further information is available, it is very common to assume independence on the probabilities of events that are linked and therefore the occurrence of one is not independent of the occurrence of the other. That is the case of probabilities of death within the members of a family. In a traffic accident, for instance, several members of a family may get injured or die and obviously these are not independent events. The spread of a disease during an epidemic outbreak is also a situation in which is very clear the dependence of probabilities of getting sick and/or dying. Stochastic dependence is not confined to this kind of contingencies; it also operates with causes of death in which the association is not so evident. In an old married couple the death of one of the spouses often foretells the death of the other in a short period of time. There are families in which a series of circumstances make more likely the death of young children and in these cases the death of a sibling increases the chances of the next child also dying. The dependence in the probabilities of death of succesive siblings could be well established with information from surveys with birth histories. In this paper, information from the World Fertility Survey (WFS) was used to adjust estimates of child mortality derived from an indirect technique for mortality estimation: the Preceding Birth Technique.

Indirect techniques are used in Demography when data on mortality or fertility are limited or defective. In general, indirect techniques for mortality estimation utilize information about the survival of a relative of the informant. There are methods that use information on the survival of the mother, the father, the spouse, siblings or children.

2. The Preceding Birth Technique

The Preceding Birth Technique (PBT) consists on asking women at a moment close to a delivery about the survival of their previous children. The proportion of preceding children dead produces an index of early childhood mortality Π or Q, that is usually (but not necessarly) close to ${}_2q_0$, the probability of dying between the birth and the second birthday. There is no need to ask dates of birth and death of the previous child, or even the age of the woman as in the classic Brass technique (Brass *et al.,* 1968), where the number of children ever born and children surviving (or dead) has to be classified according to the woman's age or marriage duration.

So far, there is a number of applications of the PBT worldwide. It has been used with data collected at maternity clinics, among other places, in Argentina (Irigoyen and Mychaszula, 1988), Bolivia (UNICEF and CELADE, 1985), Brazil (Ortiz, 1988), Honduras (UNICEF and CELADE, *op cit.*), Lebanon (Fargues and Khlat, 1989), Mali (Hill and Macrae, 1985; Hill *et al.*,1986) and the Solomon Islands (Macrae, 1979).

As mentioned before, the Preceding Birth Technique in its original form utilizes information provided by women at a time very close to a subsequent delivery. Commonly, the data is gathered at hospitals or maternity clinics to which not every woman has access. Those having their children at hospitals and clinics constitute a sub-sample of the total population of childbearing women in which younger, more educated, higher socio-economic status women may be over-represented. The children of these women are less exposed to risk of disease and death. There may also be a selection on the opposite direction, if among women delivering at hospitals there is a concentration of those with higher risk. This may be the reason that they are having their babies under special survelliance. Thus, using information exclusively from women delivering in clinics produces biased mortality estimates. Hill *et al.* (1986), for instance, found child mortality estimates inversely related to the parity of the mother. This result contrary to expectations, is just an example of how biases can be produced from using a sample of only those women delivering in maternity clinics.

A simulation of collection of information on the preceding child based on the WFS (Aguirre, 1990) showed important differentials in the index of early childhood mortality in Peru and Mexico, according to the place of delivery. The proportions of previous children dead at the time of the last delivery were 0.156 in Peru and 0.092 in Mexico for women who delivered at home. The figures for those that would have been included in the PBT sample; namely, those who had their babies at maternity clinics were 0.088 and 0.066, respectively. During the period of five years prior to the surveys, as many as 61% of the deliveries in Peru and 46% in Mexico took place at home. Since the proportions of previous children dead at national level were 0.130 in Peru and 0.078 in Mexico, someone who in the early to mid-seventies had collected information for the PBT in clinics and hospitals of Peru and Mexico intending to estimate child mortality for the whole population, would have underestimated mortality by 32% and 15%, respectively.

3. A new approach

An alternative approach that has been proposed to make the coverage more complete is to interview the women on an occasion other than at the time of delivery. The aim would be to reach all young children. Such opportunity might be provided by a health intervention, like an immunisation or nutrition programme. The most important point is that the operation is in principle intending to contact all children. Nonetheless, while coverage improves, a new source of inaccuracy arises. Only women whose children survive until the time of the intervention are contacted, and asked about the survival of the previous birth. This is again a "privileged" sub-sample, the advantage transpiring from the very fact that the last child is alive. The inexactitude produced arises because there is dependence between the probabilities of death of successive siblings. This is however a problem on which it is possible to circumvent.[1]

The problem can be posed as follows. There are two siblings, the older and the younger. Each one can be alive or dead at the moment of the intervention.

[1] Aguirre and Hill (1987) have adumbrated the approach to tackle the problem of dependence on the probabilities of death of successive siblings.

Therefore there are four possible situations:

	Older			
Younger		ALIVE	DEAD	TOTAL
	ALIVE	$\mathcal{A}$	$\mathcal{B}$	$\mathcal{A}+\mathcal{B}$
	DEAD	$\mathcal{C}$	$\mathcal{D}$	$\mathcal{C}+\mathcal{D}$
	TOTAL	$\mathcal{A}+\mathcal{C}$	$\mathcal{B}+\mathcal{D}$	$\mathcal{T}=\mathcal{A}+\mathcal{B}+\mathcal{C}+\mathcal{D}$

$\mathcal{A}$: The older and the younger are both alive. Their mother goes to have the younger vaccinated (say) and reports that the older is alive.

$\mathcal{B}$: The older is dead and the younger is alive.

$\mathcal{C}$: The older is alive and the younger is dead.

The survival of the older is not reported.

$\mathcal{D}$: Both are dead. The death of the older remains unrreported.

Let x and y be respectively the ages (or rather time since they were born) of the older and the younger. The actual probability that the older (in a pair of children) is dead is:

$$\text{Pr }\{\text{Older is dead}\} = \frac{\mathcal{B}+\mathcal{D}}{\mathcal{A}+\mathcal{B}+\mathcal{C}+\mathcal{D}} = q(x). \tag{1}$$

However, $\mathcal{C}$ and $\mathcal{D}$ are unknown for when the younger child is dead the mother is not interviewed. With the piece of information available it is possible to estimate $q(x)$ as:

$$\widehat{q}(x) = \frac{\mathcal{B}}{\mathcal{A}+\mathcal{B}}, \tag{2}$$

that is equal to the conditional probability

$$\text{Pr }\{\text{Older is dead} \mid \text{younger is alive}\}. \tag{3}$$

There is another conditional probability for which no information exists whatsoever:

$$q^c(x) = \frac{\mathcal{D}}{\mathcal{C}+\mathcal{D}} = \text{Pr }\{\text{Older is dead} \mid \text{younger is dead}\}. \tag{4}$$

The actual probability $q(x)$ is a weighted average of the last two. Similar probabilities of death for the younger can also be defined. The estimation of the probability that the older child is dead is:

$$\text{Pr }\{\text{Older dead} \mid \text{younger alive}\} = \frac{\text{Pr}\{\text{Older dead \& younger alive}\}}{\text{Pr}\{\text{Younger alive}\}}. \tag{5}$$

When there is independence:

$$\text{Pr }\{\text{Older dead \& younger alive}\} = q(x)[1-q(y)], \tag{6}$$

then

$$\widehat{q}(x) = \frac{q(x)[1-q(y)]}{1-q(y)} = q(x). \tag{7}$$

However, there is dependence between the mortality of successive siblings. In the populations studied so far, the association is positive, namely the figures in cells $\mathcal{A}$ and $\mathcal{D}$ are greater than in the case of independence. However, the developments that follow are valid for the cases where there is negative dependence.[2] This might arise if a mother with a preceding child dead was so carefully monitored that the chances of her succeeding child surviving were raised above the average.

Let the factor of dependence be f, in such a way that:

$$q^c(y) = \Pr\{\text{Younger is dead} \mid \text{Older is dead}\} = fq(y) \tag{8}$$

$f = 1$ implies independence. As the degree of dependence increases, so does f. A value of $f < 1$ means negative dependence.

When there is dependence between the probabilities, the number of cases in which both children are dead is increased (decreased) from $\mathcal{D} = \mathcal{T}q(x)\ q(y)$, to:

$$\mathcal{D} = f\ \mathcal{T}\ q(x)\ q(y). \tag{9}$$

The other cells can be obtained by subtraction:

$$\begin{aligned}
\mathcal{C} &= \mathcal{T}q(y) - f\mathcal{T}q(x)q(y) = \mathcal{T}q(y)[1 - fq(x)],\\
\mathcal{B} &= \mathcal{T}q(x) - f\mathcal{T}q(x)q(y) = \mathcal{T}q(x)[1 - fq(y)],\\
\mathcal{A} &= \mathcal{T}[1 - q(y)] - \mathcal{T}q(x)[1 - fq(y)],\\
&= \mathcal{T}[1 - [q(x) + q(y)] + fq(x)q(y)].
\end{aligned} \tag{10}$$

These relationships are considered for the adjustment of the mortality estimates. In practice, when one applies the PBT, the only estimation available is $\widehat{q}(x)$. For what has been seen above $\widehat{q}(x)$ underestimates $q(x)$ (as long as the dependence is positive). Two questions arise. First, how good an estimation of $q(x)$ is $\widehat{q}(x)$? And secondly, what adjustment is required to bring $\widehat{q}(x)$ in line with $q(x)$? From the formulae derived above, it is possible to express $\widehat{q}(x)$ in terms of f, $q(x)$ and $q(y)$:

$$\widehat{q}(x) = \frac{\mathcal{B}}{\mathcal{A}+\mathcal{B}} = \frac{\mathcal{T}q(x)[1 - fq(y)]}{\mathcal{T}[1 - q(y)]} = q(x)\frac{1 - fq(y)}{1 - q(y)} \tag{11}$$

When $f > 1$ ($f < 1$), $q(x)$ is under-estimated (over-estimated). Therefore, it is necessary a factor to make the correction. The correction factor is given by:

$$\mathcal{F} = \frac{q(x)}{\widehat{q}(x)} = \frac{q(x)}{\frac{q(x)[1-fq(y)]}{1-q(y)}} = \frac{1 - q(y)}{1 - fq(y)}. \tag{12}$$

The correction factor $\mathcal{F}$ is independent of $q(x)$. This property facilitates the handling of more complex formulae. Indeed, so far, we have considered the simplest case in which the ages of the two children are constant. f was accordingly

[2] In this situation the values in cells $\mathcal{B}$ and $\mathcal{C}$ increase relative to the case of independence, whereas $\mathcal{A}$ and $\mathcal{D}$ decrease.

defined as the factor of dependence between the mortality of pairs of children aged exactly x and y. Fixed ages for the older and younger children produce a constant birth interval $(x - y)$. However, probabilities of dying are sensitive to the length of periods of exposure and therefore factors of dependence are affected by them as well as by the length of birth intervals itself. It is then necessary to define factors of dependence in which variations in ages of the children involved are allowed. Let f_y be the factor of dependence between the probability of a child dying by age y and that of his older sibling dying by age x, where x can be any age, the only condition being that $y < x$. Hence,

$$f_y = \frac{\Pr[\text{Younger dies by age } y|\text{older dies by the time when the younger would be } y]}{\Pr\,\{\text{Younger dies by age } y\}}. \tag{13}$$

There is not a direct reference to a specific age of the older child; thus, age is allowed to vary. The birth interval is also allowed to vary under this definition. This means that the correction factor can be obtained with an analogous formula to (1) and this is valid for any x, *i.e.*,

$$\mathcal{F}_y = \frac{1 - q(y)}{1 - f_y q(y)}, \qquad \forall \;\; x > y. \tag{14}$$

The index of early chilhood mortality obtained when the PBT is applied in its original form; namely, when the questions on the survival are asked during the confinement is:

$$Q = \int_0^\infty I(x)q(x)\mathrm{d}x, \tag{15}$$

where $I(x)$ is the distribution of the older children by time since they were born or rather

$$\mathrm{Q} = \int_b^B I(x)q(x)\ \mathrm{d}x, \tag{16}$$

with b as the minimum length of a birth interval and B as the maximum length of a birth interval. Assuming the mothers are interviewed when the age of their youngest child is exactly y. The proportion of previous children dead is:

$$\mathrm{Q}_y = \int_0^\infty I(x)q(x)\ \mathrm{d}x, \tag{17}$$

or more precisely:

$$\mathrm{Q}_y = \int_{b+y}^{B+y} I(x)q(x)\ \mathrm{d}x. \tag{18}$$

Nevertheless, the available information from mothers with a surviving last child only enables us to estimate:

$$\widehat{Q}_y = \int_{b+y}^{B+y} I(x)\widehat{q}(x)\ \mathrm{d}x. \tag{19}$$

The correction factor in (14) can be applied:

$$\begin{aligned}
\mathcal{F}_y \widehat{Q}_y &= \frac{1-q(y)}{1-f_y\, q(y)} \widehat{Q}_y \\
&= \left[\frac{1-q(y)}{1-f_y\, q(y)}\right] \int_{b+y}^{B+y} I(x)\widehat{q}(x)\ \mathrm{d}x \\
&= \int_{b+y}^{B+y} I(x) \frac{1-q(y)}{1-f_y\, q(y)} \widehat{q}(x)\ \mathrm{d}x \\
&= \int_{b+y}^{B+y} I(x) q(x)\ \mathrm{d}x \\
&= Q_y.
\end{aligned} \qquad 20$$

Notice that $Q_0 = Q$, and that $\widehat{Q}_0 = Q_0$. In addition, the smaller the y is, the closer $\widehat{Q}_y$ is to Q_y.

The correction factors for the general standard of the logit life table system (Brass, 1971) with $\beta = 1$ and α varying from -1.4 to 0.4,[3], for values of f between 0.0 and 3.0, are presented in tables 1, 2, 3 and 4. The tables show the factors to correct the estimates when the questions are posed at the time the younger children are respectively 6, 12, 18 and 24 months old. The rows corresponding to $f = 1.0$ contain ones indicating that no correction is required in the case of stochastic independence. Above these rows, the values indicate over-estimation that had to be corrected with factors under 1. All this occurs with negative dependence ($f < 1$). In contrast with positive dependence there is actually under-estimation that is adjusted with factors over 1. The greater the departure from independence (the greater $\mid f - 1 \mid$), and/or the higher the mortality level (the higher α or ${}_1q_0$), the more severe the under-estimation (over-estimation) and the greater the magnitude of the correction. The severity is also increased when the younger child is older (compare between tables). From the previous discussion, a fixed age y has been used for the younger child at the time the information is gathered. In practice when the data are collected, the children the intervention is aimed at, will have different ages. Nevertheless, the ages are expected to be within a certain range. If, for instance, the health intervention is immunisation, women with children no younger than three months nor older than two years are likely to be interviewed. Even if the kind of operation involves contacting children over a longer range of ages, the analysis can be restricted to the cases when ages lies in a shorter interval, one in which the recall problems will not be considerable, say no more than three years. An estimate comparable with the "traditional" PBT would be the

[3] The level of mortality is also indicated by the infant mortality rate. The range of mortality levels covers most (if not all) likely levels of mortality of populations in which the extension of the PBT will be applied. $\alpha > 0.4$ produces extremely high mortality on one hand, and on the other, $\alpha < -1.0$ means a low level of mortality often associated to populations with a certain degree of development and reasonably good vital registration; populations in which indirect estimation is not the best approach to measure mortality.

proportion of previous children dead born to mothers who had their last child within the interval allowed, regardless whether this last child is alive or dead:

$$\underline{Q} = \int_v^V I(y) \int_{b+y}^{B+y} I(x)q(x) \,\mathrm{d}x \,\mathrm{d}y \tag{21}$$

where:

v is the minimum age for younger children,

V is the maximum age for younger children,

$I(y)$ is the distribution of the younger children by time since they were born.

Again, since not all women are interviewed the available estimation is:

$$\widehat{\underline{Q}} = \int_v^V I(y) \int_{b+y}^{B+y} I(x)\widehat{q}(x) \,\mathrm{d}x \,\mathrm{d}y. \tag{22}$$

The correction factor for this estimation is given by:

$$\phi = \frac{\underline{Q}}{\widehat{\underline{Q}}}, \tag{23}$$

which is a weighted average of the correction factors $\mathcal{F}_y$,

$$\begin{aligned}
\phi = \frac{\underline{Q}}{\widehat{\underline{Q}}} &= \frac{\int_v^V \int_{b+y}^{B+y} I(y)\ I(x)q(x) \,\mathrm{d}x \,\mathrm{d}y}{\int_v^V \int_{b+y}^{B+y} I(y)\ I(x)\widehat{q}(x) \,\mathrm{d}x \,\mathrm{d}y} \\
&= \frac{\int_v^V \int_{b+y}^{B+y} I(y)\ I(x)\widehat{q}(x) \frac{1-q(y)}{1-f_y q(y)} \mathrm{d}x \,\mathrm{d}y}{\int_v^V \int_{b+y}^{B+y} I(y)\ I(x)\widehat{q}(x) \,\mathrm{d}x \,\mathrm{d}y} \\
&= \frac{\int_v^V I(y) \frac{1-q(y)}{1-f_y q(y)} \left[\int_{b+y}^{B+y} I(x)\widehat{q}(x) \,\mathrm{d}x\right] \mathrm{d}y}{\int_v^V I(y) \left[\int_{b+y}^{B+y} I(x)\widehat{q}(x) \,\mathrm{d}x\right] \mathrm{d}y} \\
&= \frac{\int_v^V I(y)\widehat{Q}(y) \frac{1-q(y)}{1-f_y q(y)} \mathrm{d}y}{\int_v^V I(y)\widehat{Q}(y) \,\mathrm{d}y} \\
&= \frac{\int_v^V I(y)\ \widehat{Q}(y)\mathcal{F}_y \,\mathrm{d}y}{\int_v^V I(y)\ \hat{Q}(y) \,\mathrm{d}y}.
\end{aligned} \tag{24}$$

That is, an average of the $\mathcal{F}_y^{\prime}s$ over the ages of the younger children, weighted by the product $I(y)\widehat{Q}(y)$. So, the value of the correction factor ϕ then, will also depend on the distribution of ages of the younger children that may vary from population to population as well as according to the kind of health intervention implemented. Therefore, it is not possible to develop something like universal correction factors depending solely on the level of mortality. Moreover, that would be an unnecessary sophistication because a simple average must not differ greatly from ϕ. Indeed, the factors of dependence f_y vary inversely with the level of mortality. This means that most of the correction factors $\mathcal{F}_y$ in the tables are not likely to be used. And those used are relatively similar. So, although more could be done to improve the correction factor ϕ, the effort would probably prove unrewarding. A simple average of the ages of the younger children can be enough to decide which table(s) must be used (to interpolate from, for intermediate ages) to select the correction factor.

Birth histories from five surveys of the WFS programme were used to calculate empirical factors of dependence between probabilities of death of successive siblings. The selection of the countries was based in three criteria. Firstly, ages at death had to be coded month by month to be able to ascertain with accuracy whether a child had died or not for every age in months of the subsequent one. Secondly, countries with diverse mortality levels were included, to see if there is any relationship between mortality level and degree of dependence. And thirdly, worldwide geographical representation was sought. The countries, from higher to lower mortality (infant mortality rates per thousand in brackets), are Bangladesh (135), Lesotho (126), Kenya (87), Ghana (72), and Guyana (58). For the analysis of dependence data from a total of 76,371 pairs of children were used. The factors of dependence for the first sixty months of life from the five countries selected appear in Figure 1. The most remarkable result to notice is that the higher is the mortality, the lower is the dependence factor between the probabilities of death of successive siblings. A steady decline can also be observed in the factors as the age increases. The decline is more important during the first year.

4. Application

An application of the extension of the PBT is illustrated with data collected by the Mexican Institute for Social Security (IMSS), within a project on "Family planning based on reproductive risk". This project comprised the running of two parallel surveys, during the months of September and October of 1986, in the states of Aguascalientes and Queretaro. In one of the surveys women were interviewed during confinement at maternity hospitals of the IMSS. In the other, interviews were conducted in out-patient clinics of the Institute among women in childbearing ages, both if women were at the clinic demanding service or if they were there accompanying a patient to the clinic. Among a great deal of information gathered, it was asked the survival status of the preceding child in hospitals. In clinics, on the other hand, data collected comprised the survival of the second-to-last child and date of birth of the last child as well as his survival. That information is enough, respectively, to apply the PBT in its original form and the extension proposed here.

The index of early childhood mortality obtained from the survey in hospitals was 37.8 per thousand. Consistent with this result, in the survey at clinics, restricting the sample to the cases when the last child was born less than 2 years prior to the survey (to avoid recall problems), the proportion of preceding children dead was 37.1 per thousand. If only women with a surviving child are considered the proportion would be 35.1 per thousand; *i.e.*, lower for the effect of dependence.

If the information had been collected in a health intervention such that only women with a surviving child had been interviewed, we would only have the last mortality estimate; an estimate that has to be corrected for the effect of dependence. From supplementary information it is known that the average age of the children born in the last 2 years before the survey is 9.3 months. From figure 1 it can be seen that Guyana, with the lowest mortality level, the factor of dependence is almost 3.0 at 9 months. The mortality of the population used in this example is even lower, so the factor of dependence is expected to be higher. Assuming a factor of dependence of 3.0 and a mortality level at $\alpha=-1.0$ (infant mortality rate of 23 per thousand), the correction factor interpolated from tables 1 and 2 is $\mathcal{F}_{9.3} = 1.043$. The corrected estimation for the data from mothers with a surviving child interviewed at clinics is:

$$\underset{\sim}{Q} = \mathcal{F}_{9.3}\ \widehat{\underset{\sim}{Q}} = 1.043 \times 35.1 = 36.6, \qquad (25)$$

i.e., a figure closer to the one obtained with all the women in clinics as well as that from hospitals.

The population entitled to the IMSS health services is a selected one, predominantly urban and with socio-economic conditions above average. Therefore, there is not a great deal of difference between the kind of services demanded. Namely, it is basically the same women who seek obstetric and outpatient treatment at the IMSS. This explains the coincidence of the results, because the data from clinics did not increase the coverage. In fact, the purpose of this example was to test the validity of the extension of the PBT, and for this test comparable samples had to be confronted.

5. Conclusions

The correction was probably not very important given the low level of mortality of the population used to illustrate the extension to the PBT. However, the correction was on the right direction and it was of the order of magnitude it was required. In populations with higher mortality the correction will be quantitatively more important than in this example.

In conclusion, the PBT in its original form may have limited value when used in areas with small proportions of births occurring in hospitals and clinics. The attraction of the extension described here is that the basic question on the survival of the preceding born child can now be used in a much wide variety of circumstances in which coverage may be much higher.

Table 1. Correction factors for the adjustmenst of the reported proportions of previous born children dead for different degrees of dependence between the survival of successive children and varying mortality levels when the last born living children are aged 6 months.

α	−1.4	−1.2	−1.0	−0.8	−0.6	−0.4	−0.2	−0.0	0.2	0.4
q(1.0)	0.011	0.016	0.023	0.034	0.050	0.073	0.106	0.150	0.208	0.282
f										
0.0	0.992	0.989	0.983	0.975	0.963	0.946	0.922	0.888	0.842	0.781
0.1	0.993	0.990	0.985	0.978	0.967	0.951	0.929	0.898	0.855	0.798
0.2	0.994	0.991	0.987	0.980	0.971	0.957	0.937	0.908	0.869	0.817
0.3	0.995	0.992	0.988	0.982	0.974	0.962	0.944	0.919	0.884	0.836
0.4	0.995	0.993	0.990	0.985	0.978	0.967	0.952	0.930	0.899	0.856
0.5	0.996	0.994	0.992	0.987	0.981	0.972	0.959	0.941	0.914	0.877
0.6	0.997	0.995	0.993	0.990	0.985	0.978	0.967	0.952	0.950	0.899
0.7	0.998	0.997	0.995	0.992	0.989	0.983	0.975	0.964	0.947	0.922
0.8	0.998	0.998	0.997	0.995	0.992	0.989	0.983	0.975	0.964	0.947
0.9	0.999	0.999	0.998	0.997	0.996	0.994	0.992	0.988	0.982	0.973
1.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.1	1.001	1.001	1.002	1.003	1.004	1.006	1.009	1.013	1.019	1.029
1.2	1.002	1.002	1.003	1.005	1.008	1.011	1.017	1.026	1.039	1.059
1.3	1.002	1.003	1.005	1.008	1.012	1.017	1.026	1.039	1.060	1.092
1.4	1.003	1.005	1.007	1.010	1.015	1.023	1.035	1.053	1.081	1.126
1.5	1.004	1.006	1.009	1.013	1.019	1.029	1.044	1.067	1.104	1.163

Table 1. Correction factors for the adjustmenst of the reported proportions of previous born children dead for different degrees of dependence between the survival of successive children and varying mortality levels when the last born living children are aged 6 months.
(continued)

α	−1.4	−1.2	−1.0	−0.8	−0.6	−0.4	−0.2	−0.0	0.2	0.4
q(1.0)	0.011	0.016	0.023	0.034	0.050	0.073	0.106	0.150	0.208	0.282
f										
1.6	1.005	1.007	1.010	1.016	1.023	1.035	1.053	1.082	1.127	1.203
1.7	1.005	1.008	1.012	1.018	1.027	1.041	1.063	1.097	1.152	1.245
1.8	1.006	1.009	1.014	1.021	1.031	1.047	1.073	1.112	1.177	1.290
1.9	1.007	1.010	1.016	1.023	1.035	1.054	1.082	1.128	1.204	1.338
2.0	1.008	1.012	1.017	1.026	1.039	1.060	1.092	1.144	1.232	1.390
2.1	1.009	1.013	1.019	1.029	1.044	1.066	1.103	1.161	1.261	1.447
2.2	1.009	1.014	1.021	1.032	1.048	1.073	1.113	1.178	1.292	1.508
2.3	1.010	1.015	1.023	1.034	1.052	1.080	1.123	1.196	1.324	1.575
2.4	1.011	1.016	1.024	1.037	1.056	1.086	1.134	1.214	1.358	1.647
2.5	1.012	1.017	1.026	1.040	1.060	1.093	1.145	1.233	1.393	1.727
2.6	1.012	1.019	1.028	1.042	1.065	1.100	1.156	1.253	1.431	1.815
2.7	1.013	1.020	1.030	1.045	1.069	1.107	1.168	1.273	1.470	1.913
2.8	1.014	1.021	1.032	1.048	1.073	1.114	1.179	1.294	1.512	2.021
2.9	1.015	1.022	1.034	1.051	1.078	1.121	1.191	1.315	1.556	2.143
3.0	1.016	1.023	1.035	1.054	1.082	1.128	1.203	1.337	1.603	2.280

Table 2. Correction factors for the adjustmenst of the reported proportions of previous born children dead for different degrees of dependence between the survival of successive children and varying mortality levels when the last born living children are aged 12 months.

α	-1.4	-1.2	-1.0	-0.8	-0.6	-0.4	-0.2	-0.0	0.2	0.4
q(1.0)	0.011	0.016	0.023	0.034	0.050	0.073	0.106	0.150	0.208	0.282
f										
0.0	0.989	0.984	0.977	0.966	0.950	0.927	0.894	0.850	0.792	0.718
0.1	0.990	0.986	0.979	0.969	0.954	0.933	0.904	0.863	0.808	0.739
0.2	0.991	0.987	0.981	0.972	0.959	0.940	0.914	0.876	0.826	0.761
0.3	0.993	0.989	0.984	0.976	0.964	0.947	0.924	0.890	0.844	0.784
0.4	0.994	0.990	0.986	0.979	0.969	0.955	0.934	0.904	0.864	0.809
0.5	0.995	0.992	0.998	0.982	0.974	0.962	0.944	0.919	0.884	0.836
0.6	0.996	0.994	0.991	0.986	0.979	0.969	0.955	0.934	0.905	0.864
0.7	0.997	0.995	0.993	0.989	0.984	0.977	0.966	0.950	0.927	0.895
0.8	0.998	0.997	0.995	0.993	0.989	0.984	0.977	0.966	0.950	0.927
0.9	0.999	0.998	0.998	0.996	0.995	0.992	0.988	0.983	0.974	0.962
1.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.1	1.001	1.002	1.002	1.004	1.005	1.008	1.012	1.018	1.027	1.041
1.2	1.002	1.003	1.005	1.007	1.011	1.016	1.024	1.037	1.056	1.085
1.3	1.003	1.005	1.007	1.011	1.016	1.024	1.037	1.056	1.086	1.134
1.4	1.004	1.006	1.010	1.014	1.022	1.033	1.050	1.076	1.118	1.186
1.5	1.005	1.008	1.012	1.018	1.027	1.041	1.063	1.097	1.152	1.244

Table 2. Correction factors for the adjustmenst of the reported proportions of previous born children dead for different degrees of dependence between the survival of successive children and varying mortality levels when the last born living children are aged 12 months.
(continued)

α	−1.4	−1.2	−1.0	−0.8	−0.6	−0.4	−0.2	−0.0	0.2	0.4
q(1.0)	0.011	0.016	0.023	0.034	0.050	0.073	0.106	0.150	0.208	0.282
f										
1.6	1.006	1.010	1.015	1.022	1.033	1.050	1.076	1.118	1.188	1.308
1.7	1.008	1.011	1.017	1.026	1.039	1.059	1.090	1.141	1.226	1.379
1.8	1.009	1.013	1.019	1.029	1.044	1.068	1.105	1.164	1.267	1.458
1.9	1.010	1.015	1.022	1.033	1.050	1.077	1.119	1.189	1.311	1.547
2.0	1.011	1.016	1.024	1.037	1.056	1.086	1.134	1.214	1.357	1.647
2.1	1.012	1.018	1.027	1.041	1.062	1.096	1.150	1.241	1.408	1.761
2.2	1.013	1.020	1.030	1.045	1.068	1.105	1.165	1.269	1.462	1.891
2.3	1.014	1.021	1.032	1.049	1.074	1.115	1.182	1.298	1.520	2.043
2.4	1.015	1.023	1.035	1.052	1.080	1.125	1.198	1.328	1.584	2.221
2.5	1.016	1.025	1.037	1.056	1.087	1.135	1.216	1.360	1.653	2.434
2.6	1.017	1.026	1.040	1.060	1.093	1.145	1.233	1.393	1.728	2.691
2.7	1.019	1.028	1.042	1.064	1.099	1.156	1.252	1.429	1.810	3.009
2.8	1.020	1.030	1.045	1.069	1.106	1.166	1.271	1.466	1.901	3.412
2.9	1.021	1.031	1.048	1.073	1.112	1.177	1.290	1.504	2.001	3.940
3.0	1.022	1.033	1.050	1.077	1.119	1.188	1.310	1.545	2.112	4.662

Table 3. Correction factors for the adjustmenst of the reported proportions of previous born children dead for different degrees of dependence between the survival of successive children and varing mortality levels when the last born living children are aged 18 months.

α	−1.4	−1.2	−1.0	−0.8	−0.6	−0.4	−0.2	−0.0	0.2	0.4
q(1.0)	0.011	0.016	0.023	0.034	0.050	0.073	0.106	0.150	0.208	0.282
f										
0.0	0.987	0.981	0.972	0.959	0.941	0.914	0.877	0.827	0.762	0.682
0.1	0.989	0.983	0.975	0.963	0.946	0.922	0.888	0.842	0.781	0.705
0.2	0.990	0.985	0.978	0.967	0.952	0.930	0.899	0.857	0.800	0.729
0.3	0.991	0.987	0.981	0.971	0.958	0.938	0.911	0.872	0.821	0.754
0.4	0.992	0.989	0.983	0.975	0.964	0.947	0.922	0.888	0.842	0.782
0.5	0.994	0.991	0.986	0.979	0.969	0.955	0.934	0.905	0.865	0.811
0.6	0.995	0.992	0.989	0.983	0.975	0.964	0.947	0.923	0.889	0.843
0.7	0.996	0.994	0.992	0.987	0.981	0.973	0.960	0.941	0.914	0.877
0.8	0.997	0.996	0.994	0.992	0.988	0.982	0.973	0.960	0.941	0.915
0.9	0.999	0.998	0.997	0.996	0.994	0.991	0.986	0.980	0.970	0.956
1.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.1	1.001	1.002	1.003	1.004	1.006	1.009	1.014	1.021	1.032	1.049
1.2	1.003	1.004	1.006	1.009	1.013	1.019	1.029	1.044	1.067	1.103
1.3	1.004	1.006	1.009	1.013	1.019	1.029	1.044	1.067	1.103	1.162
1.4	1.005	1.008	1.011	1.017	1.026	1.039	1.059	1.091	1.143	1.229
1.5	1.006	1.010	1.014	1.022	1.033	1.049	1.075	1.117	1.185	1.303

Table 3. Correction factors for the adjustmenst of the reported proportions of previous born children dead for different degrees of dependence between the survival of successive children and varing mortality levels when the last born living children are aged 18 months. (continued)

α	−1.4	−1.2	−1.0	−0.8	−0.6	−0.4	−0.2	−0.0	0.2	0.4
q(1.0)	0.011	0.016	0.023	0.034	0.050	0.073	0.106	0.150	0.208	0.282
f										
1.6	1.008	1.012	1.017	1.026	1.039	1.060	1.092	1.144	1.230	1.388
1.7	1.009	1.013	1.020	1.030	1.046	1.070	1.109	1.172	1.280	1.483
1.8	1.010	1.015	1.023	1.035	1.053	1.081	1.126	1.201	1.333	1.593
1.9	1.012	1.017	1.026	1.040	1.060	1.092	1.144	1.232	1.391	1.721
2.0	1.013	1.019	1.029	1.044	1.067	1.104	1.163	1.265	1.454	1.871
2.1	1.014	1.021	1.032	1.049	1.074	1.115	1.182	1.299	1.523	2.050
2.2	1.016	1.023	1.035	1.053	1.082	1.127	1.202	1.335	1.599	2.266
2.3	1.017	1.025	1.038	1.058	1.089	1.139	1.223	1.374	1.683	2.533
2.4	1.018	1.027	1.041	1.063	1.097	1.152	1.244	1.414	1.776	2.872
2.5	1.019	1.029	1.044	1.068	1.104	1.164	1.266	1.457	1.880	3.315
2.6	1.021	1.031	1.047	1.072	1.112	1.177	1.289	1.503	1.997	3.920
2.7	1.022	1.033	1.051	1.077	1.120	1.190	1.313	1.552	2.130	4.795
2.8	1.023	1.035	1.054	1.082	1.128	1.204	1.338	1.604	2.282	6.173
2.9	1.025	1.037	1.057	1.087	1.136	1.217	1.363	1.660	2.457	8.663
3.0	1.026	1.039	1.060	1.092	1.144	1.232	1.390	1.719	2.661	14.518

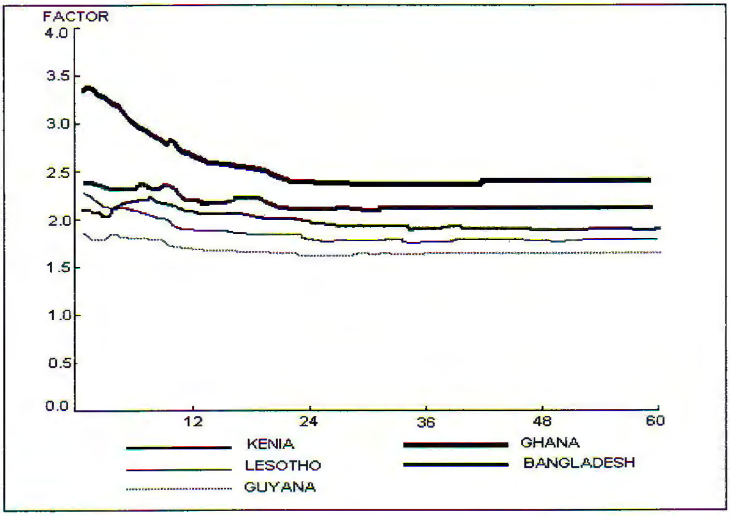
Table 4. Correction factors for the adjustment of the reported proportions of previous born children dead for different degrees of dependence between the survival of successive children and varying mortality levels when the last born living children are aged 24 months.

α	−1.4	−1.2	−1.0	−0.8	−0.6	−0.4	−0.2	−0.0	0.2	0.4
q(1.0)	0.011	0.016	0.023	0.034	0.050	0.073	0.106	0.150	0.208	0.282
f										
0.0	0.986	0.979	0.969	0.954	0.933	0.903	0.862	0.807	0.737	0.653
0.1	0.987	0.981	0.972	0.958	0.939	0.912	0.874	0.823	0.757	0.676
0.2	0.988	0.983	0.975	0.963	0.946	0.921	0.886	0.839	0.778	0.701
0.3	0.990	0.985	0.978	0.967	0.952	0.930	0.899	0.857	0.800	0.729
0.4	0.991	0.987	0.981	0.972	0.959	0.939	0.912	0.875	0.824	0.758
0.5	0.993	0.989	0.984	0.976	0.965	0.949	0.926	0.893	0.849	0.790
0.6	0.994	0.991	0.987	0.981	0.972	0.959	0.940	0.913	0.875	0.824
0.7	0.996	0.994	0.990	0.986	0.979	0.969	0.954	0.933	0.903	0.862
0.8	0.997	0.996	0.994	0.990	0.986	0.979	0.969	0.954	0.933	0.904
0.9	0.999	0.998	0.997	0.995	0.993	0.989	0.984	0.977	0.966	0.949
1.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.1	1.001	1.002	1.003	1.005	1.007	1.011	1.016	1.025	1.037	1.056
1.2	1.003	1.004	1.007	1.010	1.015	1.022	1.033	1.050	1.077	1.119
1.3	1.004	1.007	1.010	1.015	1.022	1.033	1.051	1.077	1.120	1.190
1.4	1.006	1.009	1.013	1.020	1.030	1.045	1.069	1.106	1.166	1.270
1.5	1.007	1.011	1.016	1.025	1.037	1.057	1.087	1.136	1.217	1.363

Table 4. Correction factors for the adjustment of the reported proportions of previous born children dead for different degrees of dependence between the survival of successive children and varying mortality levels when the last born living children are aged 24 months.
(continued)

α	−1.4	−1.2	−1.0	−0.8	−0.6	−0.4	−0.2	−0.0	0.2	0.4
q(1.0)	0.011	0.016	0.023	0.034	0.050	0.073	0.106	0.150	0.208	0.282
f										
1.6	2.009	1.013	1.020	1.030	1.045	1.069	1.106	1.168	1.272	1.469
1.7	1.010	1.015	1.023	1.035	1.053	1.081	1.126	1.201	1.333	1.594
1.8	1.012	1.018	1.027	1.040	1.061	1.094	1.147	1.237	1.399	1.742
1.9	1.013	1.020	1.030	1.045	1.069	1.107	1.169	1.274	1.473	1.919
2.0	1.015	1.022	1.033	1.051	1.078	1.120	1.191	1.314	1.555	2.138
2.1	1.016	1.024	1.037	1.056	1.086	1.134	1.214	1.357	1.646	2.412
2.2	1.018	1.027	1.040	1.062	1.095	1.148	1.238	1.403	1.749	2.768
2.3	1.019	1.029	1.044	1.067	1.103	1.162	1.263	1.451	1.865	3.246
2.4	1.021	1.031	1.047	1.072	1.112	1.177	1.289	1.503	1.998	3.924
2.5	1.022	1.034	1.051	1.078	1.121	1.192	1.317	1.559	2.151	4.960
2.6	1.024	1.036	1.055	1.084	1.130	1.208	1.345	1.620	2.330	6.739
2.7	1.025	1.038	1.058	1.089	1.140	1.224	1.375	1.685	2.541	10.507
2.8	1.027	1.041	1.062	1.095	1.149	1.240	1.406	1.756	2.795	23.840
2.9	1.028	1.043	1.066	1.101	1.159	1.257	1.438	1.833	3.104	−88.668
3.0	1.030	1.045	1.069	1.107	1.168	1.274	1.472	1.917	3.491	−15.503

Figure 1. Factor of Dependence between the Probabilities of Death for Succesive Siblings by Age of the Younger for Selected Countries.



Glossary

Π, Q : proportion of previous children dead.

I : mean birth interval.

${}_xq_0$, $q(x)$: probability of dying by age x. Here it is used to denote the probabilities of death of previous children or for the older in a pair of children.

${}_yq_0$, $q(y)$: probability of dying by age y. Here it is used to denote the probabilities of death of current children or for the younger in a pair of children.

I^* : age such that $\Pi = \text{q}(I^*)$.

γ : quotient of I^* over $I[\gamma = I^*/I]$.

L_x : number [proportion] of survivors to age x.

$\mathcal{A}$: number of cases in which in a pair of children, both are alive.

$\mathcal{B}$: number of cases in which in a pair of children, the older is dead and the younger is alive.

$\mathcal{C}$: number of cases in which in a pair of children, the older is alive and the younger is dead.

$\mathcal{D}$: number of cases in which in a pair of children, both are dead.

$\widehat{q}(x)$: probability that the older child is dead, given that the younger is alive.

$q^c(x)$: probability that the older child is dead, given that the younger is dead.

$\widehat{q}(y)$: probability that the younger child is dead, given that the older is alive.

$q^c(y)$: probability that the younger child is dead, given that the older is dead.

f : factor of dependence between the probabilities of death of two successive siblings.

$\mathcal{F}$: correction factor for $\widehat{\mathrm{q}}(x)$.

f_y : factor of dependence between the probabilities of death of two successive siblings, when the age of the younger child is y.

$\mathcal{F}_y$: correction factor for $\widehat{\mathrm{q}}(x)$, when the age of the younger child is y.

$I(x)$: distribution of the older children by time since they were born.

b : minimum length of a birth interval.

B : maximum length of a birth interval.

Q_y : proportion of previous children dead when the younger is (would be) y.

$\widehat{Q}_y$: proportion of previous children dead when the younger is y.

α : parameter indicating level of mortality in the logit life table system.

β : parameter indicating the pattern of mortality in the logit life table system.

$\underset{\sim}{\mathrm{Q}}$: proportion of previous children dead when mothers are contacted anytime after the confinement, regardless of the survival status of the younger.

v : minimum age for the younger children.

V : maximum age for the younger children.

$I(y)$: distribution of the younger children by time since they were born.

$\widehat{\underset{\sim}{\mathrm{Q}}}$: estimate of $\underset{\sim}{\mathrm{Q}}$ when the younger children are alive.

ϕ : correction factor for $\widehat{\underset{\sim}{\mathrm{Q}}}$.

References

Aguirre, A. (1990). The Preceding Birth Technique for the Estimation of Child Mortality: Theory, Extensions and Applications. PhD Thesis, University of London.

Aguirre, A., and A. Hill (1987). Childhood Mortality Estimates using the Preceding Birth Technique: Some Applications and Extensions, Centre for Population Studies, London School of Hygiene and Tropical Medicine. Research Paper, pp. 87-92.

Brass, W. (1971). On the Scale of Mortality. In Biological Aspects of Demography. Ed. W. Brass.

Brass, W., and S. Macrae (1985). Childhood mortality estimated from reports on previous births given by mothers at the time of a maternity. I Preceding Birth Technique. In Advances in Methods for Estimating Fertility and Mortality from Limited and Defective Data. Ed. W. Brass. Centre for Population Studies, pp. 75-86.

Brass, W., *et al.* (1968). The Demography of Tropical Africa. Princeton University Press. Princeton, N.J.

Coale, A., and P. Demeny (1966). Regional Model life Tables and Stable Populations. Princeton University Press. Princeton, N.J.

Fargues, P., and M. Khlat (1989). Child Mortality in Beirut: Six Indirect Estimates based on Data Collected at the Time of a Birth. Population Studies, London.

Guzmán, J. M. (1988). El Procedimiento del Hijo Previo: La Experiencia Latinoamericana. Seminar on Collection and Processing of Demographic Data in Latin America. Santiago de Chile, pp. 23-27 .

Hill, A., and S. Macrae (1985). Measuring Childhood Mortality Levels: a New Approach. UNICEF Social Statistics Bulletin, 8(2), Nairobi.

Hill, A., S. Traoré, F. Cluzeau, and A. Thiam (1986). L'enquéte pilote sur la mortalité aux jeunes ages dans cing maternités de la Ville de Bamako, Mali :*Estimation de la Mortalité de Jeune Enfant...*Editions INSERM 145, pp 107-30. Paris.

Irigoyen M., and S. Mychaszula (1988). Estimación de la mortalidad infantil mediante el Método del Hijo Previo. Aplicación en el Hospital Rural de Junín de los Andes. Seminar on Collection and Processing of Demographic Data in Latin America. Santiago de Chile, pp 23-27.

Macrae, S. (1979). Birth Notification Data as a Source of Basic Demographic Measures: Illustrated by Specific Application to the Study of Childhood Mortality in the Solomon Islands. PhD Thesis, University of London.

Mbacké, C. (1988). Quelques difficultés liées á la measure de la mortalité des enfants pour evaluation des programmes de Santé en Afrique. African Population Conference. Dakar 2 IUSSP.

Ortiz, L. (1988). Estimativas de Mortalidade Infantil a través do Método do Filho Prévio. Anais do VI Encontro Nacional de Estudos Populacionais, 4. Olinda, Brasil.

UNICEF (1985). Nuevo Procedimiento para Recolectar Información sobre la Mortalidad de la Niñez. Investigación Experimental en Bolivia y Honduras. CELADE series 0I(37). Santiago de Chile.

United Nation (1982). Model life Tables for Developing Countries. New York.