Estimation of Childhood Mortality from Children Ever Born and Children Surviving in Nepal

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Infant and child mortality has been recognized as an important indicator for measuring the standard of living and socioeconomic status of a country. This paper estimates infant and child mortality from data on children ever born and children's survival status by age of mother based on the Nepal Demographic and Health Survey (NDHS) 2011. We use various methods of indirect estimation such as the Trussell method (1975), the Feeney method (1976) and the Palloni and Heligman method (1986). These demographic procedures have been developed to measure fertility and mortality in developing countries, where the completeness of vital statistics registration systems is lacking. The estimation method uses data collected from surveys and censuses on number of women by age, children ever born (CEB) and children's survival status during the year preceding the survey or census. The results estimate the infant mortality rate (IMR) at 52.7 (Feeney), 54.6 (Trussell) and 54.3 (Palloni and Heligman) for the year 2008. The estimated child mortality rate (CMR) is 19.0 (Trussell) and 19.6 (Palloni and Heligman) for the reference year 2008. As the Feeney method is applicable for populations experiencing linear decline of mortality in the recent past, the estimation of the infant mortality rate based on the Feeney method (52.7 per 1,000 for year 2008) is likely to be the most reliable for Nepal. However, this estimate is slightly different from the published figure.

Keywords: *infant mortality; child mortality, children ever born, child survival; indirect estimation; Nepal*

Introduction

National statistics on infant and child mortality are among the most widely used indicators of health status, well-being and socioeconomic status (Lynch, Mineau & Anderton, 1985). The infant mortality rate (IMR) is defined as the probability of dying before the first birthday and the child mortality rate (CMR) is the probability of dying between ages one and five years. There are several factors that affect the level of IMR and CMR in a specific country, such as the nutrition of mothers and children, birth intervals, parity, age of mother at childbirth and sociocultural practices. Thus IMR and CMR usually decline with socioeconomic development, as reflected by measures of nutrition, child health and reproductive health. The analysis of infant and child mortality data is essential for planners and policy makers for the formulation of development strategies to meet the health needs of the people (Yadava & Tiwari, 2003).

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Like most developing countries, Nepal has also witnessed high infant and child mortality. However, this trend has declined over time (Ministry of Health and Population, 2012). Infant and child mortality can be estimated based on direct methods where reliable data from censuses and surveys is available. However, in most developing countries the quality of the data from the census, surveys and vital registration is not reliable. Nepal is no exception to this: births and deaths collected from the census, surveys and the vital registration system are highly under enumerated and estimations based on this information are not reliable (Patel, 2004). In order to minimize the problem of data quality, demographers have explored indirect techniques to estimate demographic parameters (Yadava & Tiwari, 2003).

The most widely used technique to estimate childhood mortality, based on the proportion of children dead amongst children ever born to women in specific age groups, was first proposed by Brass and is widely known as the Brass method. The Brass method can be applied when fertility and mortality is constant (Brass, 1975). However, in the case of Nepal, both fertility and mortality are declining, and thus this method cannot be used. Other widely used methods of childhood mortality estimation, that can be used under varying fertility and mortality scenarios, are the Trussell method, the Feeney method and the Palloni and Heligman method (Brass, 1975; Feeney, 1976; Palloni & Heligman, 1986; Sullivan, 1972; Trussell, 1975). Based on the changing mortality pattern in Nepal, this paper explores using these three methods to estimate the infant and child mortality rate.

Data and methods

Estimates are developed using data collected by the Nepal Demographic and Health Survey (NDHS) 2011. This is a nationally representative survey which included 12,674 women and 4,121 men aged 15-49 years from 10,826 households throughout the country. A two-stage sampling method was used, where in the first stage a total of 289 clusters (enumeration areas) were selected by using a probability-proportional-to-size strategy. In the second stage, 35 households were selected randomly in each urban cluster and 40 households in each rural cluster (Ministry of Health and Population (MoHP) et al., 2012).

Survey data are categorized and tabulated on the number of children ever born (CEB), number of children surviving and number of children dead classified by five-year age groups for women of reproductive age (15-49 years). For estimation of childhood mortality, the United Nations software package MortPak for Mortality Measurement is used. MortPak includes 17 applications in the area of fertility and mortality estimation and population projection. The CEBCS application provides estimations of infant and child mortality based on CEB and children surviving by age of mother (United Nations, 1983; 1988). Based on the pattern of past infant and child mortality, the Coale-Demeny West model life table and general mortality pattern of UN models for developing countries were found to be suitable for Nepal (Central Bureau of Statistics, 2014).

Theoretical Explanation of the Brass Method

Although the Brass method is not appropriate for Nepal due to its assumption that fertility remained constant in the recent past, a theoretical explanation of the method is given here because it was the basis of the methods developed by Trussell, Feeney, and Palloni and Heligman. Brass was the first demographer to develop a procedure for converting the proportion of children ever born, D_i, reported by women in five-year age groups into estimates of the probability of a child dying before attaining certain exact childhood ages, $q_{(x)}$. This can be expressed: $q_{(x)} = K_i D_i$ where the multiplier K_i is meant to adjust for non-mortality factors determining the value of D_i. Brass found that the relation between the proportion of children dead D_i, and a life-table mortality measure, $q_{(x)}$, is primarily influenced by the age pattern of fertility, because it is the pattern that determines the distribution of the children of a group of women by length of exposure to the risk of dying (Brass, 1975).

Brass developed a set of multipliers to convert observed values of D_i into estimates of $q_{(x)}$, the multipliers being selected according to the value of $P(1)/P(2)$, where P_i is the average parity or number of children ever born reported by women in the age group i. Some assumptions about the recent past are necessary to use the Brass method: that a constant pattern and level of mortality has prevailed; that fertility has been roughly constant; and that child mortality has been changing in a linear way (Brass, 1975).

Brass's method for estimating child mortality is based on an ingeniously simplified model. However, it frequently leads to values of $q_{(x)}$, the proportion of children dying by age x that are not consistent with each other. Estimation of IMR based on the 15-19 age group will be based on incidents of child death that occurred near the date of the survey, while the corresponding estimate based on the 45-49 age group will be based on deaths that occurred longer ago. Thus, the time period for each of the mortality estimates has to be estimated separately. For this reason, estimates of IMR based on the 15-19 age group are not used because of methodological problems, such as the few cases of births, and estimates of IMR based on higher age groups are not used because of reporting errors and different mortality levels in the past. The best estimate is obtained by a weighted average of the 20-24 and 25-29 age groups, where the weights are the proportion of children ever born (Brass, 1975).

Trussell Variant of Brass Method

Trussell modified the original version of the Brass method for estimating infant and childhood mortality. His method uses the same estimation procedure, using data on CEB and child survival by women's age group, but also estimates the time reference period. The reference period for child mortality is estimated as the number of years before the survey date. Child mortality can be estimated from this method for a population where mortality remains constant in the recent past. However, the fertility pattern is assumed to remain constant in the recent past and to follow a Coale-Trussell model fertility pattern (Trussell, 1975).

Trussell estimated a third set of multipliers, K_i, by using the least squares regression equation:

$$K_i = a_i + b_i\frac{P(1)}{P(2)} + c_i\frac{P(2)}{P(3)}$$

Estimates of constants were derived by studying fertility from fertility schedules and mortality from Coale–Demeny model life tables. The value of constants a_i, b_i and c_i are estimated by using regression analysis of simulated model cases for each age group of women for each of the four Coale-Demeny model life table families. Here, *i* refers to 1, 2, 3, 4, 5, 6 and 7 for $q_{(1)}$, $q_{(2)}$, $q_{(3)}$, $q_{(5)}$, $q_{(10)}$, $q_{(15)}$ and $q_{(20)}$.The reference period for child mortality is estimated as the number of years before the survey date; i.e. $t_{(x)}$ and the value of $t_{(x)}$ is calculated by the following equation:

$$t_{(x)} = a_i + b_i\frac{P(1)}{P(2)} + c_i\frac{P(2)}{P(3)}$$

where a_i, b_i and c_i are coefficients for $t_{(x)}$.

Here, the value of the multiplier for both K_i and $t_{(x)}$ are obtained from the West model of the Coale-Demeny model life tables (Trussell, 1975).

The UN created the program CEBCS to estimate IMR, CMR and expectation of life at birth based on Trussell's method. Using data on average number of children ever born, proportion of children surviving by five-year age groups of women and mean age of childbearing for Nepal in 2011, the CEBCS program estimates the value of IMR and CMR as follows (Table 1). The mortality pattern of Nepal follows the West mortality pattern of the Coale–Demeny model life tables, so the IMR and CMR values are obtained based on the West pattern of mortality from the CEBCS program. Mean age of childbearing is 27.51 (MoHP, et al., 2012) . Table 1 shows the results for infant mortality using the Trussell method.

Table 1: Estimation of IMR based on Trussell's method using CEBCS, Nepal 2011

Age groups	W_i	CEB_i	Mean CEB	Proportion of children surviving	$q_{(x)}$	$t_{(x)}$
15-19	2790	350	0.13	0.121	0.079	April 2010
20-24	2281	2210	0.97	0.909	0.058	January 2009
25-29	2129	4364	2.05	1.915	0.053	January 2007
30-34	1697	4757	2.80	2.580	0.058	July 2004
35-39	1561	5478	3.51	3.158	0.068	April 2002
40-44	1266	5104	4.03	3.499	0.081	February 1999
45-49	950	4352	4.58	3.898	0.083	February 1996
Total	**12674**	**26615**	**2.10**			

Source: MoHP, et al., 2012

The appropriate estimation of IMR is usually based on the age groups 20-24 years and 25-29 years, using a weighted average as discussed above. The weights are average CEB. From the above table, it will be (0.058 * 0.97 + 0.053 * 2.05)/(0.97 + 2.05) = 0.0546, i.e., 54.6 per 1000 live births. The reference period for the average IMR is (1 – 2009 + 1 – 2007)/2 = 1 – 2008, i.e., January 2008. It means that the reference period for IMR (i.e., 54.6/1000) is for January 2008. Table 2 shows the results for child mortality using the Trussell method.

Table 2: Estimation of CMR based on Trussell method using CEBCS, Nepal 2011

Age groups	W_i	CEB_i	Mean CEB	Proportion of children surviving	$q_{(x)}$	$t_{(x)}$
15-19	2790	350	0.13	0.121	0.035	April 2010
20-24	2281	2210	0.97	0.909	0.021	January 2009
25-29	2129	4364	2.05	1.915	0.018	January 2007
30-34	1697	4757	2.8	2.58	0.021	July 2004
35-39	1561	5478	3.51	3.158	0.027	April 2002
40-44	1266	5104	4.03	3.499	0.036	February 1999
45-49	950	4352	4.58	3.898	0.037	February 1996
Total	**12674**	**26615**	**2.10**			

Source: MoHP, et al., 2012

The appropriate estimation of CMR is usually based on women's age groups 20-24 years and 25-29 years. The estimation is derived by the weighted average, where the weights are average CEB. From the above table, it will be (0.021 * 0.97 + 0.018 * 2.05)/(0.97 + 2.05) = 0.019, i.e., 19.0 per 1000 children for those who survive to exactly age one. The reference period for the average CMR is (1 – 2009 + 1 – 2007)/2 = 1 – 2008, i.e., January 2008. It means that the reference period for CMR (i.e., 19.0) is for January 2008.

Feeney method

Feeney was the first to examine the effect of changing mortality on the performance of infant mortality estimation procedures. He modified the original version of the Brass method, which assumes constant mortality, to create a method that is equally applicable in the case where mortality is declining linearly. Feeney used data on CEB through mean age at childbearing and child survival. He developed an estimation procedure to establish the set of years to which the IMR refers in the population experiencing a linear change in IMR. The Feeney method includes some assumptions, such as that there was a linear trend of infant mortality in recent past and that mortality follows a general standard pattern (Feeney, 1976).

To estimate the IMR, Feeney calculated the mean age at childbearing using average parity ratios of successive age groups. These are calculated for the first three age groups of the reproductive ages, i.e., $P(1)/P(2)$, $P(2)/P(3)$ and $P(3)/P(4)$ for 15-19, 20-24 and 25–29 age groups respectively.

Then, the values of displacement of mean age of childbearing are identified from the mean parity ratio, and these values are added to the mean age of the corresponding successive age group to estimate mean age at childbearing for each of the first three age groups. Finally, mean age at childbearing for women is estimated by taking the average of mean ages at childbearing for the first three reproductive age groups (Feeney, 1976).

After estimating mean age at childbearing, IMR for each age group of women $_i$ are estimated by using:

$$IMR_i = \{a_i + b_i M\} D_i - c_i.$$

where M is the mean age at childbearing,
D_i is proportion of children dead for age group $_i$ and
a_i, b_i and c_i are coefficient for estimating IMR.
here, i refers to 1, 2, 3, 4, 5, 6 and 7 for the 15-19, 20-24, 25-29, 30-34, 35-39, 40-44 and 45-49 age groups of women respectively.

Finally, the reference period for IMR as the number of years before the survey date is calculated as:

$$t_{(x)} = a_i - b_i M + c_i D_i.$$

where a_i, b_i and c_i are coefficient values for estimating the reference period.

Table 3 shows the results for infant mortality using the Feeney method, with Table 4 showing the estimation of mean age at childbearing.

Table 3: Estimation of IMR based on Feeney method, Nepal 2011

Age groups	W_i	CEB_i	Mean CEB_i	No of Child deaths $(CD)_i$	$D_i = CD_i/CEB_i$	$P_i = CEB_i / W_i$	Age index, X	IMR_i	$t_{(x)}$
15-19	2790	350	0.13	25	0.07	0.13	1		
20-24	2281	2210	0.97	140	0.06	0.97	2	51.89	2.6
25-29	2129	4364	2.05	287	0.07	2.05	3	53.10	4.6
30-34	1697	4757	2.80	373	0.08	2.80	5	54.99	6.7
35-39	1561	5478	3.51	550	0.10	3.51	10	74.95	9.2
40-44	1266	5104	4.03	67	0.01	4.03	15	14.44	12.1
45-49	950	4352	4.58	648	0.15	4.58	20	87.19	15.4
Total	**12674**	**26615**	**2.10**	**2695**	**0.10**	**2.10**			

Source: MoHP, et al., 2012

Table 4: Estimation of mean age at childbearing

Age groups	P_i= CEB$_i$/W_i	$P_i/P_{(i+1)}$	Mean age	Displacement value*	Mean age of childbearing
15-19	0.13	0.13	20	+9	29.13
20-24	0.97	0.47	25	+3	28.47
25-29	2.05	0.73	30	-3	27.73
30-34	2.80				
35-39	3.51				
40-44	4.03				
45-49	4.58				
Average mean age at childbearing					28.4

* Value of displacement based on mean parity and constant a_i, b_i and c_i for IMR; time reference provided by Feeney(1976)

Here, IMR$_i$ = $\{a_i + b_iM\}D_i - c_i$. Likewise, time reference period $t_{(x)}$ = a_i- $b_iM + c_iD_i$ for i; 1 to 7 for age groups 15-19, 20-24, 25-29, 30-34, 35-39, 40-44 and 45-49 respectively. The value coefficient multiplier of IMR: a_i, b_ic_i and the value of multiplier $t_{(x)}$: a_i, b_i and c_i are obtained from the Brass Logit model life table.

Because of the small number of births, in the youngest and oldest age groups we have not estimated the IMR based on age groups 15-19 and 45-49 years. The best way of estimating IMR is usually based on age groups 20-24 years and 25-29 years. The estimation is given by the weighted average where the weights are average CEB. From the above table, it will be (51.89 * 2210 + 53.10 * 4364)/(2210 + 4364) = 52.7. The reference period for the IMR is (2.6 + 4.6)/2 = 3.6. It means that the reference period for IMR (i.e., 52.7) is 3.6 years earlier (October 2008) than that of survey period, April 2011.

Palloni and Heligman method

Palloni and Heligman modified the original Brass method of estimating child mortality (Palloni & Heligman, 1986). They formulated an equation to estimate the multiplier which is linear to a function of average parity ratios $P(1)/P(2)$ and $P(2)/P(3)$ and mean age of childbearing. In this method, mean age of childbearing is added in the multiplier function, which in turn is estimated from $P(3)/P(2)$ ratios. The reference period of child mortality, the number of years before the survey date, is independent of the rate of mortality change in this case also. There are some assumptions used by this method as well: that fertility has been constant in the recent past and follows a Coale-Trussell model fertility pattern; and that mortality follows patterns of one of the United Nations Models for Developing Countries. In this method, Palloni and Heligman formulate the following relation to estimate the value of multiplier, K_i,:

$$K_i = a_i + b_i\frac{P(1)}{P(2)} + c_i\frac{P(2)}{P(3)} + d_iM.$$

where, a_i, b_i, c_i, and d_i are the coefficients of multiplier K_i and the values are obtained based on the UN Model Life Table for Developing Countries.

Mean age of childbearing (*M)* is calculated as:

$$M= 2.25 \frac{P(2)}{P(3)}P+23.93 \text{ (Palloni, 1978)}$$

Palloni and Heligman have estimated five regression equations corresponding to five mortality patterns of the UN Model Life Table for Developing Countries with the addition of mean age at childbearing as another independent variable (Palloni & Heligman, 1986). A second set of regression equations has also been estimated to estimate time reference period.

With the help of data on average number of children ever born, proportion of children surviving by five-year age groups of women and mean age of childbearing (27.51), the CEBCS program provides the value of IMR and CMR as follows (Tables 5 and 6). The mortality pattern of Nepal falls on the general patterns of the UN Model for Developing Countries.

Table 5: Estimation of IMR using the Palloni and Heligman method by CEBCS, Nepal 2011

Age groups	W_i	CEB_i	Average CEB_i	C.S.	$q_{(x)}$	$t_{(x)}$
15-20	2790	350	0.13	0.121	0.073	February 2010
20-25	2281	2210	0.97	0.909	0.057	January 2009
25-30	2129	4364	2.05	1.915	0.053	April 2007
30-35	1697	4757	2.80	2.580	0.059	January 2005
35-40	1561	5478	3.51	3.158	0.069	May 2002
40-45	1266	5104	4.03	3.499	0.080	May 1999
45-50	950	4352	4.58	3.898	0.084	January 1996
Total	**12674**	**26615**	**2.10**			

Source: MoHP, et al., 2012

As discussed earlier, the appropriate estimation of IMR is usually based on the age groups 20-24 years and 25-29 years. The estimation is given by the weighted average, where the weights are average CEB. From the above table, it will be (0.057 * 0.97 + 0.053 * 2.05)/(0.97 + 2.05) = 0.0543, i.e., 54.3 per 1000 live births. The reference period for the average IMR is (1– 2009 + 4 – 2007)/2 = 10 – 2008. It means that the reference period for IMR (i.e., 54.3/1000) is for October 2008.

Table 6: Estimation of CMR using the Palloni and Heligman method by CEBCS, Nepal 2011

Age groups	W_i	CEB_i	Average CEB_i	C.S.	$q_{(x)}$	$t_{(x)}$
15-20	2790	350	0.13	0.121	0.032	February 2010
20-25	2281	2210	0.97	0.909	0.021	January 2009
25-30	2129	4364	2.05	1.915	0.019	April 2007
30-35	1697	4757	2.80	2.580	0.022	January 2005
35-40	1561	5478	3.51	3.158	0.029	May 2002
40-45	1266	5104	4.03	3.499	0.038	May 1999
45-50	950	4352	4.58	3.898	0.041	January 1996

Total	**12674**	**26615**	**2.10**

Source: MoHP, et al., 2012

The best way of estimating CMR is usually based on the age groups 20-24 years and 25-29 years. The estimation is given by the weighted average, where the weights are average CEB. From the above table, it will be (0.021 * 0.97 + 0.019 * 1.95)/(0.97 + 2.05) = 0.0196, i.e., 19.6 per 1000 for those who survive exact age one. The reference period for the average CMR is (1 – 2009 + 4 – 2007)/2 = 10 – 2008. This means that the reference period for CMR (i.e., 19.6/1000) is for October 2008.

Conclusion

In Nepal, where the quality of data from the vital registration system is poor, demographic parameters are often estimated based on indirect techniques. Childhood mortality is estimated based on children ever born and the proportion of children dead by age five according to the age group of the mother. Estimation based on indirect techniques is usually based on some assumptions. For example, the Brass technique assumes that fertility has remained constant in the recent past, the Trussell method assumes linear mortality changes in the recent past, the Feeney technique assumes that mortality follows general standard patterns, and the Palloni and Heligman technique assumes that mortality follows the UN model mortality for developing countries. If demographic changes are in fact different from these assumptions, estimates based on these indirect techniques will not be reliable.

Feeney modified the Brass method for measuring the infant mortality in a population experiencing a linear decline in mortality, incorporating the impact of mean age of childbearing. This method estimated infant mortality from each age group of women considering the changes of infant mortality during the years before the survey (Feeney, 1976). The demographic analysis of Nepal suggests that both fertility and mortality declined over the time period, though the decline in the rate of mortality rate is higher than that of fertility (MoHP, et al., 2012)

Hence, the estimation of infant mortality by the Feeney method (52.7 per 1000 for the reference period October 2008) is likely to be the most appropriate estimate. However, the estimated IMR and CMR from indirect methods differ from the published reports (IMR, 46 and CMR, 9 for 0-4 years preceding the survey 2011), requiring further research and analysis.

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