Estimation of Adult Mortality from Widowhood Information

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Introduction

Most of the developing countries of the third world, either have an inadequate or virtually no vital registration system. The data collected from the population censuses in these countries are defective. In this situation it is hardly possible to measure mortality directly. So demographers have tried to develop indirect methods in order to overcome this problem. A widely known indirect method of estimating adult mortality is the Orphanhood method developed by Brass and Hill [5]. The method has been applied to a wide range of the populations in the developing regions particularly several African and Latin American countries, and has been found to yield a reasonable level of adult mortality.

Orphanhood Method

The orphanhood method has been developed on the basis of simple questions, such as "Is your mother/father still alive?" The results, tabulated by the sex and age group of respondents, thus reflect levels of adult mortality. The relationship between orphanhood and certain life table functions is examined by means of suitable model life tables. This has been done for a range of age groups of respondents, and for a range of age locations of fertility. These model relationships are then assumed to be applicable to real situations. The orphanhood method of estimating adult mortality can then be linked with estimates of infant and child mortality, to generate a suitable life table.

Here an attempt will be made to describe the Brass and Hill method and for the sake of convenience female mortality estimation will be considered first. Let us suppose a group of respondents aged "a" years are survivors of

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births that occurred "a" years ago and if "a" years ago, the number of women aged t was A (t), and the probability of having a child at age t was f(t), then the number of children born "a" years ago c(a) is given by:

$$c(a) = \int_{\alpha}^{\beta} A(t)\, f(t)\, .\, dt \qquad \ldots \qquad \ldots \qquad (1)$$

where α and β represent the earliest and latest ages at which child bearing occurred. The probability of a mother surviving from exact age t to exact age t+a is $l_{(t+a)}/l_{(t)}$, where $l_{(t)}$ is the probability of surviving from birth to age t. Hence, the proportion of mothers still surviving will be:

$$p(a) = \frac{\int_{\alpha}^{\beta} A(t)\, f(t)\, \frac{l_{(t+a)}}{l_t}.\, dt}{\int_{\alpha}^{\beta} A(t)\, f(t).\, dt} \qquad \ldots \qquad \ldots \qquad (2)$$

Now considering the age distribution of the original women by stable population model is such that:

$$A(t) = Ke^{-rt} l_{(t)}$$

and equation (2) can be written as:

$$p(a) = \frac{\int_{\alpha}^{\beta} e^{-rt} f(t)\, l_{(t+a)}\, .\, dt}{\int_{\alpha}^{\beta} e^{-rt} f(t)\, l_t\, .\, dt} \qquad \ldots \qquad \ldots \qquad (3)$$

From the above equation the proportion not orphaned can be estimated by using Brass model fertility and mortality schedules. Brass used a simple polynomial function of the form:

$f(t) = c(t\text{-}s)\ (s+33-t)^2$ to represent the fertility distribution and the General Standard life table for the mortality distribution [2]. Life table survivorship probabilities from an arbitrary base age B to age B+N are related to the proportions not orphaned in pairs of age groups centred on age N. Weights are developed for this purpose, according to the estimating equation:

$$l_{(B+N)}/l_{(B)} = W(N)_5P_{N-5} + \{1 - W(N)\}_5P_N$$

where ${}_5P_N$ is the proportion of mothers surviving for the age group of length 5 years.

The values of weights (W) were calculated for different values of N and for a variety of locations of the child bearing period. These weights are applied to reported proportions not orphaned, to estimate the life table survivorship probabilities of the actual population. The relevant set of weights for the application to a specific population is determined on the basis of the mean age of child bearing in the population. B which is a base is fixed at 25. Trial calculations show that it is the most convenient value when applying the method. The method for estimating male adult mortality from survivorship of fathers is very much the same.

Widowhood Method

Information is collected on the survival of the first spouse by asking a simple question, such as "Is your first Husband/Wife still alive?" Responses by females about their first husbands provide information about male adult mortality, and responses by males about their first wives provide information about female adult mortality.

The analysis of information on widowhood to estimate adult mortality has some apparent advantages over the analysis of information on orphanhood. The marriage function has a minimum variance, thus reducing the extent of possible deviations from model assumptions. In the orphanhood method no reliance can be placed on information from respondents under age 20, because of the bias involved due to the adoption of orphaned children by related families. This type of bias is not present in the analysis of widowhood information. Although remarriages may distort the estimation, it is possible to obtain estimates from reports of young adults, who will not have been married long, whose exposure to risk of widowhood is short, and whose widowhood experience thus reflects very recent mortality levels [13, 14].

As mentioned by Hill, some serious problems are also involved in the analysis of widowhood information. The widowhood information may be seriously distorted by remarriages. In order to avoid this difficulty, data must be collected on the survival of the first spouse, although such a limitation may introduce data accuracy problems. The second problem is posed by the measurement of exposure to risk of widowhood. In the case of orphanhood, the exposure to risk of maternal orphanhood is equal to the age of the respondent, and exposure to the risk of paternal orphanhood is approximately equal to the age of the respondent plus three quarters of a year for the female gestation period. No such simple relationship exists with widowhood, unless the proportion widowed can be tabulated by first marriage. If this fails then a given exposure to the risk of widowhood and the female marriage distribution, will be used to determine the exposure to risk in each age group. Some of these advantages and disadvantages are theoretical, and some are concerned with data. The method of estimating proportions widowed of first spouse by duration of marriage is the same as that of estimating proportions orphaned by age. Starting with widowhood, let the number of males aged t, "a" years age be A(t). If the distribution of male marriages to single women, by age, is described by the function f(t), the number of males marrying "a" years ago will be given by:

$$\int_{\alpha}^{\beta} A(t)\, f(t)\, .\, dt$$

where α and β are the earliest and latest ages at which males marry. The probability of surviving from exact age t to exact age t+a is $l_{(t+a)}/l_{(t)}$, so the proportion of women who are involved in marriage and not widowed after "a" years of marriage is:

$$p(a) = \frac{\int_{\alpha}^{\beta} A(t)\, f(t)\, l_{(t+a)}\, .\, dt / l_{(t)}}{\int_{\alpha}^{\beta} A(t)\, f(t)\, .\, dt}$$

In a stable population, the number of males aged t, "a" years ago can be described in terms of the mortality schedule and the rate of population growth by the equation.

$A(t) = Ke^{-rt}\, l_{(t)}$, so the proportion of women whose first husbands will still be alive after exactly "a" years is:

$$p(a) = \frac{\int_{\alpha}^{\beta} e^{-rt}\, f(t)\, l_{(t+a)}\, .\, dt}{\int_{\alpha}^{\beta} e^{-rt}\, f(t)\, l_t\, .\, dt} \quad \ldots \quad \ldots \quad (3)$$

which is exactly equivalent to equation (2). The application of the method to the populations of developing regions faces a serious problem. In most statistically underdeveloped countries, age reporting is grossly inaccurate, so it would be unreasonable to expect accurate reporting of one particular period of that age.

Proportions Widowed Given a Fixed Female Age at Marriage

If all women, who ever get married for the first time did so at exact age "b", a women now aged exactly "a" will have been exposed to the risk of widowhood from her first husband for exactly a – b years. If the age distribution of the males marrying single females is described by f(t), the proportion widowed amongst the females aged b, p(b), will be:

$$p(b) = \frac{\int_{\alpha}^{\beta} e^{-rt} f(t) \, l_{(t+a-b)} \, . \, dt}{\int_{\alpha}^{\beta} e^{-rt} f(t) \, l_{(t)} \, . \, dt} \quad \ldots \quad \ldots \quad (4)$$

where α and β are the age limits of t. Given a marriage function evaluated for single years, proportions widowed for intervals of single years can be calculated and these may be directly weighted to estimate the proportion widowed in an age group of women.

In order to make the necessary calculations, it is important to give some numerical form to the first marriage distribution, to survivorship probabilities and to the rate of population growth. Coale has developed female first marriage distribution model [10]. This model was found to give an excellent fit to observed female first marriage distributions from a variety of developing countries, and it was also found to give an adequate fit to a variety of male first marriage distributions. However, Coale's model requires two fitting parameters, one for age location, and one for the rate at which marriages then occur. This introduces a degree of sophistication which is not in keeping with the assumption that the concentration of all respondents' marriages is at the mean.

The use of simple polynomials, was felt to be more suitable by Hill. This feeling came from his thorough examination of available first marriage distributions amongst which he found considerable variation. Thus the polynomials chosen are intended to represent a situation in the middle of extreme situations. In his analysis he has observed that the actual form of the function chosen has but a negligible effect on the estimates of widowhood. The female first marriage distribution is represented by the function $f(t) = t^{1/3}(30-t)^4$ and the male first marriage distribution is represented by $f(t) = t^{1/2}(30-t)^3$. Both functions have the same range of 30 years. The mean of the female function is 6.3 years, with 90 percent married after 12.8 years; the mean of the male function is 8.3 years, with 90 percent married after 15.5 years. Survivorship functions were taken from a Brass model life table based on his General Standard having an $l_{(2)}$ of 800. The rate of population growth was assumed to be two percent per annum.

Estimation of Male Adult Mortality from Proportions of Widowed Females

The precise form of the estimating equation used to relate proportions of women not widowed to survivorship probabilities is crucial, though the closer the correspondence of the two the better. The exposure to risk at a particular age varies with the mean age at marriage, so it is desirable to use different estimating equations for different means. Proportions of women not widowed in two adjacent age groups are related to the probability of survivorship to the central point of the two age groups by the use of weights. This system of weighting adjacent age groups introduces a useful element of smoothing into the estimation process. When the mean age at first marriage for the female respondents is below 20, the estimating equation used is:

$$l_{(N+5)} / l_{22\frac{1}{2}} = W(N)_5 P_{N-5} + \{1 - W(N)\}_5 P_N,$$

where N is the central point of the adjacent age groups, and P is the proportion not widowed in an age group. For respondents 20 to 24 and 25 to 29, N will be 25, so the survivorship ratio estimated will be $l_{(30)}/l_{22\frac{1}{2}}$, a survivorship of 7½ years from an age of 22½. If males marry on average five years later than females, their exposure to risk will start from around 22½ if all females marry at 17½. Thus wives aged 25 will have husbands who have survived from 22½ to 30. Where the mean age at female marriage is above 20, the estimating equation used is:

$$l_{(N+5)}/l_{27\frac{1}{2}} = W(N)_5 P_{N-5} + \{1 - W(N)\}_5 P_N$$

With the male respondents, it is the male first marriage distribution which determines the exposure to risk, and the female first marriage distribution which determines the level of the risk. Otherwise, the situation is the same as for female respondents. For a mean age of male marriage below 25, the estimating equation used is:

$$l_{(N-5)}/l_{17\frac{1}{2}} = W(N)_5 P_{N-5} + \{1 - W(N)\}_5 P_N,$$

where N is the central age of two male age groups, and P is the proportion not widowed of first wife. For example, for age groups 25 to 29 and 30 to 34, N equals 30, so the survivorship ratio is $l_{(25)} / l_{17\frac{1}{2}}$, a survivorship of 7½ years from age 17½. In an analogous fashion, if the mean age at male marriage is between 25 and 30, the estimating equation used is:

$$l_{(N-5)} / l_{22\frac{1}{2}} = W(N)_5 P_{N-5} + \{1 - W(N)\}_5 P_N$$

The Application of the Method to the Pakistan Census Data

Data on marital status in the 1961 census of Pakistan are available. From this information proportions widowed can be easily calculated. Brass felt that these proportions reflect, in a crude way, the level of adult mortality. But widowhood information from census data is distorted by the presence of remarriages. Thus it is not possible to use census information on widowhood directly unless one takes into account the proportion who are remarried.

Widow Remarriages

For the estimation of adult mortality from information on widowhood, we need to know the period of exposure to risk, which is not determinable if data on the survival of the first spouse are not available; the reason is that the proportion of widow remarriages may distort the adult mortality level. In the absence of reliable information on widow remarriage, Brass suggested that a trial and error value of P (proportion remarried) can be taken and then fitted to a model life table (for example, Coale and Demeny [11] system of model life tables) in order to find a more consistent value of P. However, if the information on the survival of the first spouse and ever widowed are available then this can be estimated by Brass' formula [4].

$P = W_{Ex} - W_x / 1 - W_{Ex}$, where P is the proportion of those widowed who remarried. W_{Ex} is the proportion ever widowed and W_x is the proportion currently widowed (reported in the census).

Estimation of Proportion of Never Widowed

By applying the value of P (the proportion of those widowed who remarried for an age group) mentioned above we can estimate the proportion of those ever widowed by Brass' formula [4].

$$W_{Ex} = W_x + P / 1 + P$$

Now subtracting from one, we can estimate the proportion never widowed and this is shown in Table 1.

Table 1

Estimation of Adult Mortality from Widowhood Information (Female Respondents) Pakistan: 1961

Age Groups	Reported proportion of widowhood	Expected[1] proportion of widowhood	Proportion never widowhood	Weighting[2] factors (W_i)	$l_{N+5} / l_{22\frac{1}{2}}$
20—24	0.0136	0.0423	0.9577	0.5021	0.9451
25—29	0.0210	0.0676	0.9324	0.5598	0.9150
30—34	0.0355	0.1069	0.8931	0.6215	0.8851
35—39	0.0583	0.1281	0.8719	0.6814	0.8523
40—44	0.1247	0.1895	0.8105	0.7268	0.7999
45—49	0.1666	0.2283	0.7717	0.7453	0.7459
50—54	0.2758	0.3294	0.6706	0.7566	0.6629
55—59	0.2970	0.3609	0.6391	0.7138	—

[1]Expected proportion of widowhood has been estimated after taking into account the trial and error values of 'p' (the proportion remarried) i.e. values which are consistent with the model life tables.

[2]The weighting factors have been chosen on the basis of the mean age at marriage of both male and female respectively [14]. The mean age at marriage for males has been taken as 23.5 years and for females as 17.6 years [1].

Life Table Construction

When life tables are to be generated from childhood mortality information and from the survival probabilities from age 22½, derived from the widowhood techniques, direct calculations are usually not possible since the mortality between age 2 and 22½ is not known. There is no complete answer as to how these two fragmentary functions should be linked. However, Brass and Hill suggested a method by means of which this is possible [5]. Taking an estimate of childhood mortality (usually l_2), as a starting point, a first value of $l_{(22\frac{1}{2})}$ is obtained from Brass' one parameter logit model [3] (i.e. by assuming that $\beta = 1$). Thus values of l_{N+5} can be estimated from $l_{N+5}/l_{22\frac{1}{2}}$. Using logit equation, a series of estimates of β, one for each value of N, can be estimated as:

$$\beta = Y_{5+N} - Y_{(2)} / Y_{s(5+N)} - Y_{s(2)}$$

where $Y_{(2)}$ is the observed logit of l_2 and $Y_S(2)$ is the standard logit; N is the central age of the respondents. A first estimate of β is then taken as the average of a range of estimates based on the reports from the most reliable group of respondents. From this first estimate of β, a new value of $l_{22\frac{1}{2}}$ is calculated, and the entire process is repeated to produce a second approximation of β. It is possible to refine this estimate by further repetitions of the procedure, but in practice it has been found that the second estimate is sufficiently accurate for most practical purposes [5]. The results are produced in Tables 2 and 3 respectively. The first estimate of average β produces an estimate of $\beta = 0.90$, the range of estimates being from 0.86 for a central age of 50 to 0.97 for a central age of 25. The estimates of β are rather erratic. A sex differential has already been introduced into the estimates of childhood mortality. It is impossible to make any firm assertion as to whether male adult mortality should be relatively higher than that of females. In most western populations male adult mortality is relatively higher than female adult mortality but this is not true in some populations of the developing countries, especially in Asia. However, the expectation of life at birth which was estimated from the widowhood information, seems to be plausible.

Conclusion

The attempt to analyze information on widowhood from first spouse was undertaken in the hope that a reasonable indirect method of estimating adult mortality (particularly male adult mortality), in statistically underdeveloped countries would result. The development of the orphanhood method has proved disappointing both theoretically and practically [14, 15]. The widowhood method, however, shows distinct promise for estimating male mortality, and seems likely to be almost as satisfactory as in the estimation of female mortality. It is more robust to deviations from its assumptions than the original orphanhood method. It is also less affected than the orphanhood method by multiple reporting of the same event. However, it is obviously too early to assert that the widowhood method is an important advance. Many more applications are required, in a wide range of cultures, before any such claim can be made. The application of the method to the Pakistan data (females respondents) produces a plausible result ($e^o_o = 47$ years). This result is consistent with one of the earlier estimates of expectation of life for Pakistan [1]. Although the method has produced a reasonable level of

Table 2

Estimation of Adult Mortality from Widowhood Information (Female Respondents) Pakistan: 1961

Central age (N)	$\frac{l_{N+5}}{l_{22\frac{1}{2}}}$	l_{N+5}[1]	First Estimate of implied β	Average β	Second[a] Estimate of implied β	Average β
(1)	(2)	(3)	(4)	(5)	(6)	(7)
25	0.9451	0.6763	0.97	—	0.91	—
30	0.9150	0.6548	0.94	—	0.89	—
35	0.8851	0.6334	0.91	—	0.87	—
40	0.8523	0.6099	0.88	0.90	0.84	0.87
45	0.7999	0.5724	0.88	—	0.85	—
50	0.7459	0.5338	0.86	—	0.84	—
55	0.6629	0.4744	0.87	—	0.86	—

[1]The estimates in column (3) have been obtained by multiplying values under column (2) with $l_{22\frac{1}{2}}$; $l_{22\frac{1}{2}} = 0.7156$ has been estimated from the Brass logit model $Y_{(x)} = \alpha + \beta\, Ys_{(x)}$, assuming $\beta = 1$ and having a child mortality level l_2. But for the period in question there is no estimate available for the child mortality. So child mortality has been estimated from the Brass one parameter model life table [9] on the basis of estimated infant mortality rate (131 per thousand live births) in 1961, derived from the National Impact Survey [1].

[a]Implied β has been calculated from the following formula,

$\beta = Y_{(2)} - Y_{(N+5)} / Ys_{(2)} - Ys_{(N+5)}$, where $Y_{(2)}$ is the logit of l_2 ($l_2 = 0.820$), $Ys_{(x)}$ is the logit of the Brass standard life table, and N is the central age.

For the second estimate of implied β, $l_{22\frac{1}{2}} = 0.7275$, $\alpha = -0.1145$, $\beta = 0.90$, $l_2 = 0.820$.

Table 3

Construction of Brass Two Parameter Abridged Life Table (for Female)

Having $\alpha = -0.1360$, ***and*** $\beta = 0.87$

Age	$Y_{S(x)}$	$\beta Y_{S(x)}$	$\alpha + \beta Y_{S(x)}$	l_x	${}_nL_x$	T_x	e^o_x
0	—	—	—	10000	8991[1]	479138	47.9
1	−.8670	−.7543	−.8903	8558	32492[2]	470147	54.9
5	−.6015	−.5233	−.6593	7889	39063	43655	55.5
10	−.5498	−.4783	−.6143	7736	38395	398592	51.5
15	−.5131	−.4464	−.5824	7622	37640	360197	47.3
20	−.4551	−.3959	−.5319	7434	36552	322557	43.4
25	−.3829	−.3331	−.4691	7187	35325	286005	39.8
30	−.3150	−.2741	−.4101	6943	34098	250680	36.1
35	−.2496	−.2172	−.3532	6696	32815	216582	32.3
40	−.1817	−.1581	−.2941	6430	31395	183767	28.6
45	−.1073	−.0934	−.2294	6128	29735	152372	24.9
50	−.0212	−.0184	−.1544	5766	27710	122637	21.3
55	+.0832	+.0724	−.0636	5318	25210	94929	17.8
60	+.2100	+.1827	+.0467	4766	22070	69717	14.6
65	+.3746	+.3259	+.1899	4062	18228	47647	11.7
70	+.5818	+.5062	+.3702	3229	13695	29419	9.1
75	+.8673	+.7546	+.6186	2249	8873	15724	7.0
80	+1.2490	+1.0866	+.9506	1300	4708	6851	5.3
85	+1.7555	+1.5273	+1.3913	583	2143*	2143	3.7

[1] $L_0 = 0.31_{0} + 0.71_1$

[2] $L_1 = 1.41_1 \ \ 2.61_5$

*Assuming $e^o_0 = 45$ years and also assuming every one dies after age 85+
The $_\infty L_{85}$ can be estimated from the Brass one parameter model life tabel as

$$\frac{_\infty L_{85}}{l_{85}} = \frac{y}{l_{85}}, \quad \frac{y}{583} = \frac{1103}{300}. \text{ Therefore, } y = 2143.$$

adult mortality, there still remains a question about the reliability of the Pakistan data, which has not been explored in this study. In order to prove the method a success, further research regarding the applicability of the Pakistan data would seem in order.

Also in the absence of any information on widow remarriages such trial and error values of proportions remarried have been considered which are consistent with model life tables. It is still questionable whether these proportions remarried, reflect the true situation, even though the result seems to be fairly reasonable.

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