Demography India
Vol.18(1989),pp.27-38

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Life Table Analysis of Censored Data on Post-Partum Amenorrhoea Period

1. Introduction

LIFE table technique has been extensively used to analyse demographic data relating to waiting time for birth, marriage, migration, mortality, etc., in recent years (Cox and Oakes 1984; Elandt-Johnson and Johnson 1980; Espenshade 1983; Pathak and Ram 1989; Rodriguez and Hobcraft 1980; Rogers and WiUekens 1986).

The technique is essentially based on the concept of exposure to the risk of the event under consideration, happening in specified durations. Among others, two main assumptions involved are, (a) the population is homogeneous with respect to the characteristic under study, and (b) there is no connection between censoring and occurrence of the event. A population is said to be homogeneous if and only if all its members are subjected to the same conditional probability of experiencing the event at duration, say T, given that they are at risk (of experiencing the event) as at time T. The independence of failure and censoring mechanisms implies, for example, that individuals are not selectively censored because of a relatively poor or relatively good prognosis (Namboodiri and Suchindran 1987).

In surveys, termination of post-partum amenorrhoea (PPA) period is noted up to a date (reference date) fixed in advance. In several cases, specially when the duration of enquiry is relatively short and the births occurring at different time points before the reference date are included in the study, the females are still in PPA on the reference date and thus their time of termination is not known. Also some females are lost to observation due to various reasons (migration, absence, non-cooperation, etc.) even before the fixed date. Obviously, both the situations are similar and hence are considered generally, in a group known as withdrawal, continuing or censored cases for the purposes of estimating conditional probability of termination of PPA in an interval and survival function in life table analysis. A detailed account of such situations is given in Cox (1983), Eland-Johnson and Johnson (1980), and Lawless (1982).

Under certain conditions the actuarial estimates of the conditional probability of termination in any interval are identical with the corresponding maximum likelihood estimator (Elandt-Johnson 1977) and several tests for comparing survival functions have been developed in recent years.

The objective of this research is to present a short description of life table methodology to analyse data on the duration of PPA which contains a considerable number of censored

cases, and obtain corresponding survival function. The method is applied to data taken from a research project entitled 'Effect of Socio-Cultural Factors on Determinants of Fertility in Eastern Uttar Pradesh (Rural)' conducted under the auspices of the Centre of Population Studies, sponsored by the Indian Council of Medical Research, New Delhi during 1987-90. The survival functions of PPA relating to the educational status of the husband are compared with a test given by Peto and Pike (1973). The methodology and a short description of data are given in Section 2. The survival functions of PPA relating to different education groups are obtained in Section 3. The homogeneity of survival functions is examined in Section 4, Conclusions are given at the end.

2. Methodology and Data

2.1 *Methodology*

Consider a survey where information on length of PPA period relating to last birth before the reference date has been collected. According to convenience the analysis may relate to the last birth within a limited period (two, three, five or more years) of time from the reference date.

Let the reference period of enquiry be divided into n subgroups, $B\backslash, 62, \ldots, B_n$ defined below:

Bi : (bi-\, bi), (i = 1, 2, . . . , n) is the i^{th} interval of width *hi = bi - bi-i,* where *bo* = 0.

Ai : the number of females who terminate PPA on or before the reference date in the interval *Bi.*

Ci : the number of females who are in PPA on the reference date in the interval *Bi,*

Ti : cumulative sum of *Am + Cm* for *m = i, i*+ 1 , . . . , n at the beginning of the interval *Bi.*

Ti : the adjusted number of females at the beginning of the interval *Bi,* that is, the number of females at risk at the beginning of the interval *Bi.*

qi : estimated conditional probability of completing PPA period during the interval *Bi* conditional on remaining in PPA at the beginning of the interval. HerePi, = 1 - *qi.*

Si : the estimated proportion of females in PPA period at the beginning of the interval *Bi.*

fi : the estimate of the probability of ending PPA period in the interval *Bi.*

It can be seen that:

$$T_i = \sum_{m=i} (A_m + C_m), \text{ and}$$

$$T_i' = T_i - C_i/2$$

The factor *Ci/2* is used *in* an attempt to adjust for the fact that not all the *Ti* females are at risk throughout the interval Bi. The standard life table estimate, *qi,* is obtained by the formula:

$$q_i = B_i / T_i \quad \text{and}$$

$$p_i = 1 - q_i$$

The survival functions S, is estimated by computing the continued products of the/?,"s. For example Si = *p1, S2 = P1P2, S3* = $P_1P_2P_3$ and so on. Let $p_0 = 1$ thus, Si, the survival function at the beginning of the i^{th} interval, i = 1,2,... is given by:

$$Si = P_0P_1 \cdot \cdot Pi\text{-}1Pi \text{ and}$$

$$fi — Si\text{-}1 — Si \quad i = 1, 2,..., n$$
$$fn+1 = Sn$$

2.2 *Data*

Data are taken from a survey, 'Effects of Socio-economic Factors on Determinants of Fertility in Eastern Uttar Pradesh (Rural)' conducted by the Centre of Population Studies, Banaras Hindu University in 1988. Eastern Uttar Pradesh comprising 17 districts, with total population of more than 40 million is a thickly populated region with low per capita income. The majority of the people, specially in rural areas, are poor and illiterate. Caste is an important determinant of occupation, education, social and economic status *in* the community. In Eastern Uttar Pradesh more than 90 per cent households are Hindus belonging to about 35 castes. These were grouped in three categories on the basis of homogeneity in the pattern of living and relative importance of caste in the area (see Singh 1989). Muslims were treated as a single group.

In the project it was decided to select three districts, namely Azamgarh, Ghazipur and Varanasi, from eastern Uttar Pradesh and collect information on various items from ab. • 350 households belonging to each caste-group from each selected district. Information was collected from the households using quota sampling procedure. If, however, a village was included in the sample, information was collected from all the households of that village irrespective of caste. There are 4,448 households in the sample. 1 October 1987 was the reference date for Azamgarh and Varanasi, while it was 1 October 1988 for Ghazipu[r]

Information on marriage, education, birth record, etc. was obtained by the it ale investigator from the female partner of each eligible couple. A couple was defined elig. 3le (Pandey and Talwar 1987) if both the partners were alive and the age of the female was .. ss than 50 years on the reference date of the survey (for details see Singh 1989). Informa .ion on PPA was obtained from the eligible female. Data on PPA, relating to the last birth within the preceding three years from the reference date was collected from only those eligible females who were available at the time of survey or resurvey to give information personally.

The impact of education on duration of PPA is reported in several studies. Though the mechanism through which education affects the PPA period is not known, the inverse relation between them is observed. Since female education is negligible in the rural areas under study, variation in the duration of PPA is examined with respect to the education of the husband. The distribution of PPA relating to last birth during the preceding three years is available for 1205, 543 and 917 (total 2665) cases for husbana s education groups I, II and III, which correspond, respectively, to education up to 4th class, from 5th to 9th class and 10th class and above.

3. Survival Function

3.1 *Observed distribution*

The observed distributions of duration of PPA, for the husband's education groups I, II and III are given in the first three columns of Tables 3.1, 3.2 and 3.3. There are both terminated and continuing cases, because observations relite to births within the preceding three years from the reference date.

TABLE 3.1 : SURVIVAL FUNCTION OF PPA RELATING TO LAST BIRTH IN EASTERN UTTAR PRADESH (RURAL): HUSBAND'S EDUCATION GROUP I, 1988

PPA (in months)	*Ai*	*Ci*	Ti	*T'i*	*qi*	*Pi*	*s(t)*	*f(t)dt*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0-3	376	159	1205	1125.5	0.3341	0.6659	1.0000	0.3341
3-6	53	45	670	647.5	0.0819	0.9181	0.6659	0.0545
6-9	52	58	572	543.0	0.0958	0.9042	0.6114	0.0586
9-12	38	61	462	431.5	0.0881	0.9119	0.5528	0.0487
12-15	149	58	363	334.0	0.4461	0.5539	0.5041	0.2249
15-21	62	33	156	139.5	0.4444	0.5556	0.2792	0.1241
21-27	34	20	61	51.0	0.6667	0.3333	0.1551	0.1034
27 +	00	7	07	3.5	0.0000	1.0000	0.0517	0.0517
Total	764	441						

Ai: Attained, Ci *:* Continuing, *Ti:* Cumulative frequency, Ti; = *T'i* — Ci / 2

Column 1 of the above noted tables give the time interval used for grouping the observations. The first interval (0,3) includes all PPAs whose durations are equal to or greater than zero but less than three months, that is, it includes all PPAs, *t,* such that $0 \leq t < 90$ days. A similar procedure is adopted for intervals (3,6), (6,9), (21,27) and the interval 27+ includes durations more than or equal to 27 months. Column 2 shows the number of terminations occurring during respective intervals, while column 3 represents the number

TABLE 3.2 SURVIVAL FUNCTION OF PPA RELATING TO LAST BIRTH IN EASTERN UTTAR PRADESH (RURAL): HUSBAND'S EDUCATION GROUP II, 1988

PPA (in months)	*Ai*	*Ci*	*Ti*	*T'i*	*qi*	*Pi*	*S(t)*	*f(t)dt*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0-3	191	64	543	511.0	0.3738	0.6262	1.0000	0.3738
3-6	34	24	288	276.0	0.1232	0.8768	0.6262	0.0771
6-9	25	24	230	218.0	0.1147	0.8853	0.5491	0.0630
9-12	16	31	181	165.5	0.0967	0.9033	0.4861	0.0471
12-15	60	15	134	126.5	0.4743	0.5257	0.4390	0.2082
15-21	23	17	59	50.5	0.5455	0.5446	0.2308	0.1051
21-27	09	05	19	16.5	0.4545	0.4545	0.1257	0.0686
27 +	01	04	05	03.0	0.3333	1.6667	0.0571	0.0571
Total	359	184						

Ai : Attained, C; : Continuing, *Ti !.* Cumulative frequency, T'i = Ti—ci /2

TABLE 3.3 SURVIVAL FUNCTION OF PPA RELATING TO LAST BIRTH IN EASTERN UTTAR PRADESH (RURAL) : HUSBAND'S EDUCATION GROUP III, 1988

. *PPA (in months)*	*Ai*	Ci	*Ti*	*T'i*	*qi*	*Pi*	*s(t)*	*f(t)dt*
(1)	*(2)*	*(3)*	*(4)*	*(S)*	*(6)*	*(7)*	*(8)*	*(9)*
0-3	411	94	917	870.0	0.4724	0.5276	1.0000	0.4724
3-6	46	43	412	390.5	0.1171	0.8822	0.5276	0.0622
6-9	58	26	323	310.0	0.1871	0.8129	0.4654	0.0870
9-12	37	39	239	219.5	0.1686	0.8314	0.3784	0.0638
12-15	95	22	163	152.0	0.6250	0.3750	0.3146	0.1966
15-21	27	09	46	41.5	0.6506	0.3494	0.1180	0.0768
21 +	01	09	10	05.5	0.1818	0.8182	0.0412	0.0412
Total	675	242						

Ai : Attained, Ci: Continuing, *T;*: Cumulative frequency, *T'i = Ti* _ Ci / 2

of withdrawals or continuing cases on the reference date. If the continuing (censored) cases are ignored, it is seen that PPA of about 49 per cent (376/764) x 100 of females are terminated within the first three months for husband's education group I. The corresponding percentages for the husband's education groups II and III are about 53 and 61,

From the figures in the first three columns of Table 3.1, 3.2 and 3.3, some tentative conclusions may be drawn: (a) The patterns of distribution of PPA in the three tables are similar in the sense that the largest number of females terminate PPA within the first three months and then the frequencies decrease in each case. Of course, there is some concentration in the interval 12-15 months, (b) From the percentages of terminations in the first three months and average durations of PPA calculated from only attained PPA, for the distributions in Tables 3.1, 3.2 and 3.3, it may be concluded that the higher the education of the husband, the smaller the duration of PPA.

3.2. *Estimation of survival function*

The technique, described in Section 2, is utilised to obtain the survival functions for the data in Tables 3.1, 3.2 and 3.3. The different steps involved in the procedure are given in columns 4,5,6,7, and 8 of the respective tables. The estimates of proportion (probability) of terminating PPA during the intervals (0,3), (3,6) etc. are given in column 9. For convenience, . the technique is illustrated with data in Table 3.1.

Column 4 of Table 3.1 gives the cumulative observed frequency starting from the bottom. For example, against the interval 12-15 months the frequency in column 4 is 363 which is obtained by adding the number of cases where the durations of PPA are more than or equal to 12 months. The values of Ti, the number exposed to the risk of termination, is obtained on the assumption that the continuing cases are distributed uniformly in the respective intervals. Thus Ti = *Ti-Ci/2.* For example, Ti = 1205-159/2 = 1125.5, T_2 = 670 - 45/2 = 647.5 and so on. Column 6 gives the estimate of q_{ii} the conditional probability of termination in the i^{th} time interval among the cases exposed to the risk in the beginning of the interval. Thus the figures in column 6 are obtained, as quotient of those in column 2 divided by the corresponding figures in column 5. The corresponding value of P, is given *by Pi* = 1 - *qi. i* = 1,2,3,... . Column 8 gives the survival function, which is estimated by calculating the continued products *of Pi's.* In the present case, *s(3),* the value of survival function at 3, is equal to *pi, s(6) = p1p2, s(9) = p1p2p3* and so on. Here, for convenience, it is assumed that P*0* = 1, so that for the i^{th} interval *Si = pop1, pi*> for *i* = 1,2,. For example in Table 3.1, s(0) = 1.0000, s(3) = 0.6659,s(6) = *p0p1p2* = 1 x 0.6659x0.9181 = 0.6114 and so on. In fact this function gives the estimate of the proportion of females still in PPA at the beginning of the interval. The last column gives the probability of attaining PPA during the corresponding interval. For the i^{th} interval, fi = Si-i - *Si* for *i* = 1, 2,. Thus *f(O) = S(0) - S(3) = 0.3341,f(3) = S(3)-S(6) = 0.0545 etc*.

4. Comparison of Survival Functions

4.1 *Graphic representation* -

Usually graphic representations are used to demonstrate the differences among a number of survival functions representing different situations. The graph of survival functions in column 9 of Tables 3.1,3.2,3.3 is given in Figure-4.1. The different curves relate to husband's education groups I, II and III. It can be observed that the curves for the three groups are distinct in the sense that none of them cross the remaining ones at any point of time. It is

important to note that there are large differences in the first interval, where the corresponding probabilities are 0.3341,0.3748 and 0.4724 for education groups I, II and III. It is interesting to observe that the three curves are almost parallel to each other after three months time. The constant difference between the curves for education groups II and III is a little larger than that between the curves for groups I and n. These figures exhibit variation in the PPA period according to education of husband.

4.2 *Statistical tests*

Graphic representations are useful to demonstrate the differences among distinct survival functions. But in several cases it is difficult to tell whether there are real differences among

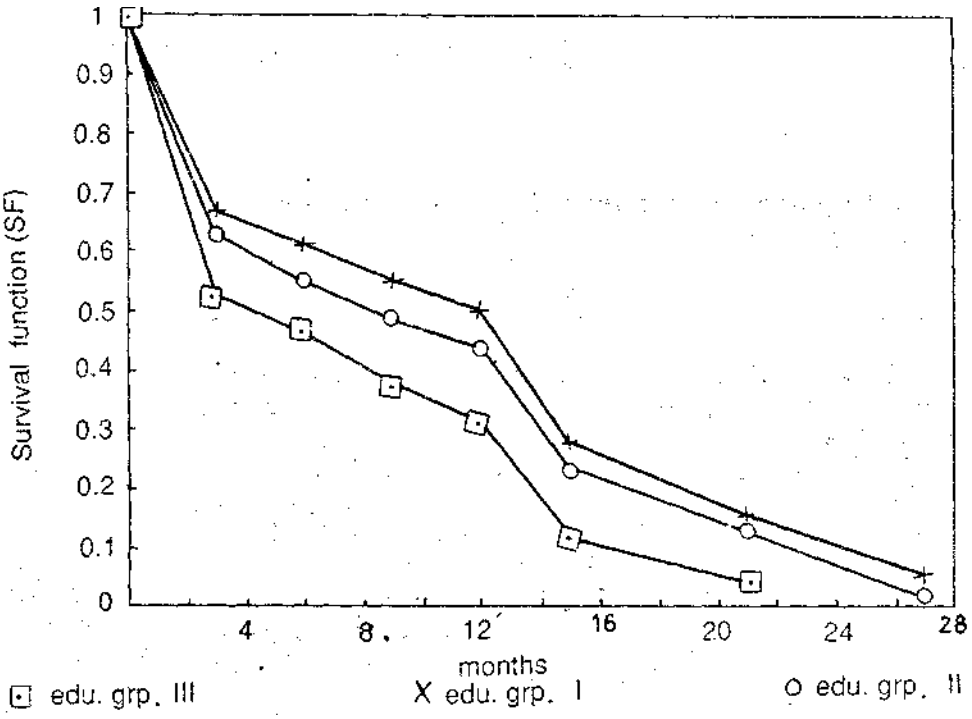

Figure 4.1 SF of PPA for Different Education Groups.

the survival functions or the visual differences are simply due to chance. In such circumstances the application of appropriate tests, if available, is often recommended. Sometimes, conditional probabilities, *qi,* conditional expectation and medians of future lifetime are compared and differences are examined with appropriate tests of significance (Elandt-Johnson and Johnson 1980). During the last 20 years, however, several tests (mostly non-parametric) have been proposed to compare the survival functions in general. In the present case the Peto and Pike (1973) ^-sample test (given below) for comparing survival function is used to examine the differences among the three survival functions relating to husband's education groups I, II and III.

4.3 *k-sample test of survival function*

Suppose we have k (≥ 2) samples of survival times and the problem is to decide whether they belong to the same population of survival times. For testing this hypothesis Peto and Pike (1973) proposed a k-sample test, which can be described as follows: suppose that in a pooled sample, failures occur at times $t_1 < t_2 < t_3 < \ldots < t_n$. Let n_{ij} be the number of individuals in j^{th} sample still at risk just prior to t_i, and let C_{ij} be the number of failures in j^{th} sample at time t_i. Let the corresponding numbers in the pooled sample be n_{i+} and C_{i+} respectively ($n_{i+} = \sum_j n_{ij}$ and $C_{i+} = \sum_j C_{ij}$). Under the hypothesis of no difference between samples, the conditional expected value of C_{ij}, given by n_{ij} can be estimated as $E_{ij} = n_{ij}\ (C_{i+} / n_{i+})$. Let $E_{+j} = \sum_i E_{ij}$. Then the test statistic suggested by Peto and Pike is:

$$\sum (E_{+j} - C_{+j})^2 / E_{+j}$$

which is treated as a Chi-square with $(k - 1)$ degrees of freedom, k being the number oi samples involved.

4.4 *Application of the test*

Let us apply the above test to examine the hypothesis that there are no differences among the survival functions given in Tables 3.1,3.2 and 3.3. The procedure is illustrated in Table 4.1. The first column of the table represents the length of the class interval. Columns 2,4; 5,7 and 8,10 are taken, respectively, from Tables 3.1,3.2 and 3.3. The figures in columns 11 and 12 are pooled data for different intervals. For example, the frequency in column 11 corresponding to the interval [0,3) is 376+191+411 = 978 and in column 12 is 1125.5+511+870 = 2506.5. Thus the expected frequency in column 3 is 978 x (1125.5/2506.5) = 439.1. Following the same procedure the expected frequencies in column 3,6 and 9 are obtained. The total observed and expected frequencies are 764,359,675 and 884.6,370.4,543.0 respectively. The calculated value of X^2 for 2 degrees of freedom is 48.88 which is much larger than 5.99, the tabulated value of X^2 for 2 degrees of freedom at 5 per cent level. Hence the hypothesis of no difference is rejected. It may be concluded that the duration of PPA is affected by the educational level of the husband.

The durations of PPA reported in Tables 3.1,3.2 and 3.3 relate to births occurring during the preceding three-year period from the reference date. It is worthwhile to examine whether the duration of enquiry can be reduced to one or two years. For this purpose the distributions of PPA corresponding to births during the last one year, the last one to two years and the last two to three years are obtained. The figures re'ating to terminating cases are given in columns 2,5 and 8 in Table 4.2 of husband's education group I and those corresponding to exposed to the risk, calculated in the usual way, are given in columns 4,7 and 10. For the application of Peto and Pike's test, the related expected frequencies, calculated with

TABLE 4.1 : COMPARISON OF SURVIVAL FUNCTIONS ACCORDING TO HUSBAND'S EDUCATION

Husband s education group											
PPA (in months)		*I'*			*II*			*III*	*Total*		
	Ai	*Ei*	Ti,	*Ai*	*Ei*	*Ti*	*Ai*	*Ei*	*Ti*	Ai	*Ti*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
0-3	376	439.1	1 125.5	191	199.4	511.0	411	339.5	870.0	978	2506.5
3-6	53	65.6	647.5	34	27.9	276.0	46	39.5	390.5	133	1314.0
6-9	52	68.4	543.0	25	27.5	218.0	58	39.1	310.0	135	1071.0
9- 12	38	48.1	431.5	16	18.4	165.5	37	24.5	219.5	91	816.5
12- 15	149	165.8	334.0	60	62.8	126.5	95	75.4	152.0	304	612.5
15-21	62	67.5	139.5	23	24.5	50.5	27	20.0	41.5	112	231.5
21-27	34	29.7	51.0	09	9.6	16.5	01	4.7	08.0	44	75.5
27 +	00	0.4	03.5	01	0.3	03.0	00	0.3	02.5	01	09.0
Total	764	884.6		359	'370.4		675	543.0		1798	

Ai: Observed attained, *Ei :* Expected attained, Ti : Exposed X^2 (calculated) = 48.88 for two degrees of freedom.

TABLE 4.2. TESTING THE HOMOGENErfY OF SURVIVAL FUNCTIONS RELATING TO LAST BIRTH IN DIFFERENT TIME PERIODS: HUSBAND'S EDUCATION GROUP I.

	Last birth between										
	1st Oct. 1986 to 30th Sept. 1987			*1st Oct. 1985 to 30th Sept. 1986*			*1st Oct. 1984 to 30th Sept. 1985*			*Total*	
PPA (in months)	*Ai*	*Ei*	*Ti*	*Ai*	*Ei*	*Ti*	*Ai*	*Ei*	*Ti*	*Ai*	*Ti*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	(9)	*(10)*	*(11)*	*(12)*
0-3	129	135.1	404.5	148	146.0	437.0	99	94.9	284.0	376	1125.5
3-6	27	15.0	183.5	20	23.7	289.0	06	14.3	175.0	53	647.5
6-9	08	10.1	105.0	32	25.8	269.0	12	16.1	169.0	52	543.0
9- 12	07	3.3	37.5	24	20.9	237.0	07	13.8	157.0	38	431.5
12 - 15	-	-		87	82.1	184.0	62	66.9	150.0	149	334.0
15-21	-	-	-	22	22.9	51.5	40	39.1	88.0	62	139.5
21-27	-	-	-	04	05.7	08.5	30	28.3	42.5	34	5!.0
27 +	-	-	-	-	-	-	00	00.0	03.5	00	3.5
Total	171	163.5		337	327.1		256	273.4		764	

Ai: Observed attained, Ei : Expected attained, *Ti :* Exposed X^2 (calculated) = 1.75 for two degrees of freedom.

procedure, described earlier, are given in columns 3,6 and 9. The calculated value of X^2 *is* 1.75 for two degrees of freedom which is less than the tabulated value 5.99 for two degrees of freedom at 5 per cent level of significance. Hence, it may be concluded that the data for the three different periods represent the same pattern in husband's education group I. The same may hold for the other two groups. This does not rule out response or non-response bias or errors but it does indicate that, if there are any such biases they are in the same direction in the three time periods. In any event, serious biases may not be present because the data relate to the recent past (the preceding three years from the reference date).

Conclusions

The duration of PPA, a component of birth interval, has been an important topic for research. It is demonstrated that its duration depends on lactation and other socio-cultural factors such as education, health, urbanity, work, tradition, etc. In most cases, except lactation, the mechanism through which these factors affect the duration of PPA is not known. Yet, it is reported that education, work, health and urban residence are inversely related to the duration of PPA.

In the present study raw data (without any smoothing) relating to duration of PPA for births to females in rural areas of three districts: Azamgarh, Ghazipur and Varanasi in Eastern Uttar Pradesh, within the preceding three years from a reference date in October 1987 are analysed with the help of life table technique dealing with censored data. It is observed that in about 33,37 and 47 per cent cases for husband's education groups I, II and III, the duration of PPA is terminated within the first three months. Indirectly these figures reveal that husbands' education influences PPA, Incidentally, these percentages get inflated to 49,53 and 61 if the continuing/censored cases are ignored; hence censored cases must be included in the analysis.

No termination of PPA in less than 35 days was reported. Hence, the average duration of PPA calculated with survival functions and mid points of intervals 2,4.5,7.5,10.5,13.5, 18,24 and 30 months are 11.17,10.12 and 7.57 for the education groups I, II and III. Thus the education of the husband beyond high school has considerable impact on the duration of PPA.

The test for homogeneity of survival functions reveals that the patterns of distribution of PPA for three educational groups are significantly different. With the same test, it is also shown that, depending on circumstances, the period of enquiry may be considerably reduced without affecting the results provided all available information including censored data is utilised.

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