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Adolescent Sterility and Time required becoming Susceptible for Conception

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Abstract: **The interval between marriage and first conception leading to a live birth plays an important role in determination of fertility of a female. One of the proximate determinants of natural fertility is fecundability, which is defined as the probability of conception that a married female will conceive during a month of exposure under unprotected cohabitations. Thus, waiting time to first conception is used to study the fecundability, adolescent sterility and the time required to become susceptible for conception. In this study, real data sets are used to check the suitability of the model and for estimation of parameters, maximum likelihood method has been used. Also an attempt has been made to show the relation ship between adolescent sterility and time require to be ready for the conception. Inverse relationships between them have been observed. The estimate of fecundability is 0.041 for the first data set (1969-70) and 0.057 for the second data set (2014-15) however the estimate of adolescent sterility is higher for first data set than second data set.**

Index Terms: **Fecundability, Waiting time to first conception, Adolescent sterility.**

I. Introduction

Fertility analysis has the central importance in demographic analysis as births are a vital component and responsible for population growth in the developing countries as well as in the underdeveloped countries. Human fertility is a complex concern of research and it is controlled by a number of biological and behavioural factors. Apart from these factors, it is also regulated by some socio-economic and cultural factors. To improve our understanding of the possible reasons of variation in fertility, it is essential to analyse the fertility mechanism through the factors influences this. It is well known the fertility behavior of a couple in the early part of their marital life, especially just after the age at marriage, is governed by a large number of socio-cultural factors. As a result, researchers have shown their larger interest in the study of this aspect of human fertility.

To determine these factors as well as tempo and quantum of fertility in the society, different type of birth intervals such as first birth interval, last closed birth interval, most recent closed birth interval, straddling birth interval, interior birth interval and forward birth interval offer an interesting and rich area for scientific research. Among these, the first birth interval plays an important role in determination of fertility level of the society because the length of first birth interval can be considered as the start of parenthood, i.e., the couple start their reproductive process with the first conception. Therefore, the timing of first birth can be considered an actual measure of fecundability if the female is adequately mature at the time of marriage. In this study, we have proposed a stochastic model for better description of the distribution of time of first conception.

The process of human reproduction starts from the onset of marriage or menarche whichever occurs latter and following this depends on a biological characteristic of a couple which is known as fecundability. The term fecundability is an important biological determinant of fertility, which regulates the actual number of children produced by the female. Fecundability is defined as the probability that a married females will conceive during a lunar month of exposure under unprotected cohabitations. Since fecundability is the monthly chance of conception thus it can be defined as inverse of the waiting time required for a conception, but this time cannot be measured directly and due to this reason data on birth interval can be used. The analysis of waiting time to first conception has some special and unique features to investigate. This interval signifies couple’s fertility at an early stage of married life. The interval is largely governed by fecundability because no female generally

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prefers to use contraception to postpone the first birth in the society. It is also free from the period of post-partum amenorrhea (PPA) associated with a live birth, also in the traditional society the females usually do not use any type of contraception before giving first birth. Other birth intervals are heavily affected by the erratic fluctuations of PPA.

In general the data on waiting time suffers from considerable degree of errors due to recall lapse which ultimately results in digit preference, misplacements of dates of required data etc. In such situation construction of probability models is perhaps the most appropriate way to minimize the effects of these types of errors due to the fact that a probability model smoothes the data and provides a reasonable explanation of phenomenon understudy. In literature the development of probability models from marriage to first conception or the birth has been considered taking time to be discrete as well as continuous. The representation of data on first birth interval to determine fecundability considering probability model has attracted the attention of Statisticians as well as Demographers for over a period of time. Gini (1924) first used geometric distribution to estimate the mean fecundability from the data on number of menstrual cycles for first conception to a cohort of married females.

The parameter p; $0<p<1$, which is the probability of conception to a female who is exposed in each menstrual cycle which may be treated equivalent to one month and also each menstrual cycle represents an independent trial. It has been observed that for a homogeneous group of females, the reciprocal of mean waiting time for first conception gives the arithmetic mean of fecundability, whereas, for a heterogeneous group of females it gives the harmonic mean of fecundability. Henry (1953) and Vincent (1961) developed number of models to study the natural fertility through the first birth interval. Potter and Parker (1964) and Sheps (1964) proposed generalised expressions by incorporating the chance of foetal losses before the first live birth.

Another extension of the above model is that some females conceive prior to the marriage and report to have conceived in the first month of marriage. James (1963), Singh (1961) and Pathak (1967) used the inflated geometric distribution. Das Gupta and Hickman (1974) suggested a model which was generalised by Suchindran and Lachenbruch (1974) to make provision for intervening foetal wastage before first live birth. Singh (1964) obtained a relation between fecundability and waiting time to conception treating time to be continuous instead of discrete as considered by Henry (1953) and Vincent (1961). For a continuous time model, one can use exponential distribution assuming the parameter as fecundability but in the case of heterogeneity it may not be suitable. Hence Singh (1964) assumed type III pearsonian distribution and applied compound exponential distribution to estimate fecundability. Pathak and Prasad (1977) derived a simple model assuming two groups of females, one is mature and exposed to the risk of conception at the time of marriage and other is not, further Nair (1983a and 1983b) and Agrafiotis (1986) extended this model. Singh (1982) have proposed a modified probability distribution for the waiting time to first conception taking into account premarital conceptions as well as the termination of study after a certain period of time. Mishra et al. (1984) proposed a truncated model for adolescent sterility assuming temporary separation follows geometric distribution. For the time of first birth Bhattacharya (1986) derived a model under the assumption that the exposure to the risk of conception is delayed due to visit of the females to her parent’s house and hence the fecundability is less in the beginning and as age advances it reaches maximum and then decreases with increase in age.

Bhattacharya et al. (1986 and 1988) derived a model for the time of first birth under the assumption that the exposure to the risk of conception is delayed due to visit of the females to her parent’s house and hence the fecundability is less in the beginning and as age advances it reaches maximum and then decreases with increase in age. Also, this interval has been found to be significantly influenced by several socio-demographic variables (Singh, 1992; Nath, 1995). Some models accounted for the concept of premarital conception (Singh et al., 2017) but in the Indian perspective, there is no chance of pre-marital conception. Singh (1964), Pathak and Prasad (1977) have assumed that many of the females may not be exposed to the risk of conception at the time of marriage because of either the presence of adolescent sterility or the prevalence of various taboos and cultural practices especially in the light of low age at marriage. In this scenario, Singh (1964) has made an adjustment of 6 months in the first birth interval for the rural areas of Varanasi. The objective of the present paper is to understand the fertility behaviour of females near the time of marriage using waiting time to conception and the approach of the probability model.

II. Model

Nowadays the females are enough mature at the time of survey thus the effect of various taboos and cultural practices on the coital behaviour of such females may also not be affected significantly. Thus, it seems reasonable that a probability model assuming all females to be fecund at the time of marriage and assuming a constant fecundability from the marriage till the first conception may be an appropriate assumption.

Let X denote the time between marriage and the first conception. Obviously, on the basis of above assumption, the probability density function of X is given as

$$f(x,\lambda) = \begin{cases} \lambda e^{-\lambda x} & x, \lambda > 0 \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

Here λ represents the conception rate per unit of time. This also represents the reciprocal of average number of conceptions per unit of time. If the unit of time is taken as one month, this may be treated as equivalent to fecundability. However, in many of the cases the researchers have taken the unit in years and thus λ is referred to as conception rate. The discrete analogue of the proposed model is the geometric distribution with the unit of time as one month or the length of menstrual cycle for homogeneous and heterogeneous group of females (Singh et al., 2018). If we assume that there is one to one correspondence between the conception and live birth then the distribution of time of first birth becomes a displaced exponential distribution with mean $\left(\frac{1}{\lambda}+g\right)$, where '*g*' is the gestation period associated with a birth. Though there can be minor variations in the value of '*g*' among females (Singh et al., 2017) but for all practical purposes the value of '*g*' is taken as 9 months or 0.75 year.

It is worthwhile mention here is that although the age at marriage is quite large but not same for all females at the time of survey. Due to this randomness in age at marriage and some other biological and nutritional factors, the susceptibility level to conception is different among the females. Female with lower age at marriage may be in the state of adolescent sterility while for some females, the cultural taboos reducing coital frequency may also be operating the value of fecundability at the time of marriage. Thus we may consider that all the females to be exposed to the risk of conception at the time of marriage may not be appropriate. Thus, if we assume that α proportion of females are exposed to the risk of conception at the beginning of the period and (1-α) proportion females become susceptible after some time (say 't') after the marriage. It is difficult to guess a proper value for the time during which the female is not exposed to risk of conception and the exact value of α. Thus, either we estimate these parameter (i.e. α and t) from the data using appropriate estimation technique or assume the values of these parameter.

Under the above assumptions, let us define a random variable X that is the time of first conception from marriage considered as a mixture of two random variables X_1 and X_2 as $\alpha X_1 + (1-\alpha)X_2$, where X_1 has the probability density function (pdf) $f_1(x)$ given as

$$f_1(x) = \begin{cases} \lambda e^{-\lambda x} & x, \lambda > 0 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

and X_2 has the pdf $f_2(x)$ given as

$$f_2(x) = \begin{cases} \lambda e^{-\lambda(x-t)} & x > t,\ \lambda > 0 \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

and thus the pdf of X can be written as

$$f(x) = \alpha f_1(x) + (1-\alpha) f_2(x)$$

This can also be written as

$$f(x) = \begin{cases} \alpha\lambda e^{-\lambda x} & \text{if } 0 < x \le t \\ \alpha\lambda e^{-\lambda x} + (1-\alpha)\lambda e^{-\lambda(x-t)} & \text{if } x > t \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

and the cumulative distribution function (cdf) is

$$F(x) = \begin{cases} \alpha\left[1-e^{-\lambda x}\right] & \text{if } 0 < x \le t \\ \alpha\left[1-e^{-\lambda x}\right] + (1-\alpha)\left[1-e^{-\lambda(x-t)}\right] & \text{if } x > t \end{cases} \quad (5)$$

III. Estimation Procedure

In this study we have discussed method of moment (MOM) as it is easier than the method of maximum likelihood. It has less mathematical complexity and no need of programming. Obviously, the first two moments of the model discussed in equation (4) are given as

$$E(X) = \alpha\left(\frac{1}{\lambda}\right) + (1-\alpha)\left(\frac{1}{\lambda}+t\right) \quad (6)$$

$$E(X^2) = \alpha\frac{2}{\lambda^2} + (1-\alpha)\left[\left(\frac{1}{\lambda}+t\right)^2 + \frac{1}{\lambda^2}\right] \quad (7)$$

$$\Rightarrow \frac{2\alpha}{\lambda^2} + \frac{1}{\lambda^2} + \left(\frac{1}{\lambda}+t\right)^2 - \frac{\alpha}{\lambda^2} - \alpha\left(\frac{1}{\lambda}+t\right)^2$$

$$= \frac{2\alpha}{\lambda^2} + \frac{1}{\lambda^2} + \frac{1}{\lambda^2} + \frac{2t}{\lambda} + t^2 - \frac{\alpha}{\lambda^2} - \frac{\alpha}{\lambda^2} - \frac{2\alpha t}{\lambda} - \alpha t^2$$

$$= \frac{2}{\lambda^2} + \frac{2t}{\lambda}(1-\alpha) + t^2(1-\alpha) \quad (8)$$

Now from equation (4)

$$E(X) = \frac{\alpha}{\lambda} + \frac{1}{\lambda} + t - \frac{\alpha}{\lambda} - \alpha t = \frac{1}{\lambda} + t(1-\alpha)$$

Hence $1-\alpha = \left[E(X) - \frac{1}{\lambda}\right]\frac{1}{t}$ (9)

Now putting $(1-\alpha)$ from equation (9) in equation (8), we have

$$E(X^2)=\frac{2}{\lambda^2}+\frac{2}{\lambda}\left[E(X)-\frac{1}{\lambda}\right]+t\left[E(X)-\frac{1}{\lambda}\right] \quad (10)$$

With the help of the above equation (10) we can get the estimate of λ for an assumed value of 't'. The estimate of α can be found using equation (9).

IV. Data

For the application of model two data sets at various time point has been used. First date set is taken from "A Demographic Survey of Varanasi (Rural)" which was conducted by the Demographic Research Centre, Banaras Hindu University, Varanasi in 1969-70. The second data set is taken from NFHS-4 (IIPS, 2017) for Varanasi Districts. The reference date of the NFHS-4 data is mentioned as 2015-16. We have considered those females whose age at marriage is more than or equal to 16 years and marital duration is more than 10 years at the time of survey, for the analysis of waiting time to first conception. Since data on waiting time to first conception cannot be obtain directly and is not available with NFHS-4. NFHS-4 provided data on first birth interval thus we subtract 9 months from the data on first birth interval for obtaining waiting time to first conception. The mean and standard deviation of the waiting time to first conception for first data is 33.08 and 24.68 months respectively and for the second data set it is 22.48 and 17.56 months respectively.

V. Application Of Model

Table 1 show that observed and expected distribution of females according to the waiting time to first conception in Varanasi district for the first data (1969-70). The chi square value=8.09 and p-value=0.23 shows the model is appropriate for the waiting time to first conception under the said assumptions. Also Table 2 reveals that same for the second data (NFHS-4). The chi square value=5.10 and p-value=0.28, indicates the model is good for this data set also. The estimated values of λ, the fecundability is found to be 0.041 for the first data set and 0.057 for the second data set. Yearly chance of conception i.e. conception rate is 12 times the fecundability is 0.492 and 0.684 respectively for both data sets. The inverse of the value of fecundability provides average waiting time. Therefore, female in Varanasi district take on an average 23.4 and 17.5 months to get first conception respectively for both data sets. The fecundability for older data set is lower than the newer data set indicates that the declining impact of socio-cultural factors and taboos on the couple's coital behaviour. Also the estimate of adolescent sterility (1-α) is higher for older data set (1969-70) than newer data set (2014-15) due to lower age at marriage in 1969-70. Therefore the value of t=9 months for older data set and t=6 months for newer data set has been considered. The values of λ seem to be low but similar low values have also been reported in many studies especially conducted in the Eastern Part of Uttar Pradesh (Singh et al., 2006; Yadava et al., 2009). Most of the reasons mentioned above are perhaps, also responsible for getting relatively low estimate of the conception rate in the early part of married life.

Table 1: Observed and expected number of females according to the waiting time to first conception in Varanasi (1969-70)

Waiting time to first conception (in months)	Observed number of females	Expected number of females	Estimate of parameters	Test criterion
<15	108	88.17	t = 9 months α = 0.056 λ = 0.041	χ^2 = 8.09 p-value = 0.23
15-27	97	113.83		
27-39	63	69.88		
39-51	44	42.90		
51-63	26	26.34		
63-75	16	16.17		
75-87	11	9.93		
87-99	7	6.09		
≥ 99	11	9.69		
Total	**383**	**383.00**		

Table 2: Observed and expected number of females according to the waiting time to first conception in Varanasi NFHS-4 (2015-16)

Waiting time to first conception (in months)	Observed number of females	Expected number of females	Estimate of parameters	Test criterion
<15	177	193.03	t = 6 months α = 0.158 λ = 0.057	χ^2 = 5.10 p-value = 0.28 after pooling
15-27	125	126.93		
27-39	72	63.74		
39-51	40	32.01		
51-63	17	16.07		
63-75	10	8.07		
75-87	4	4.05		
87-99	1	2.04		
≥ 99	2	2.05		
Total	**448**	**448.00**		

In Table 3 we have tried to show the variation of average and standard deviation of waiting time to first conception according to different level of fecundability, proportion of adolescent sterility and time required becoming susceptible for conception.

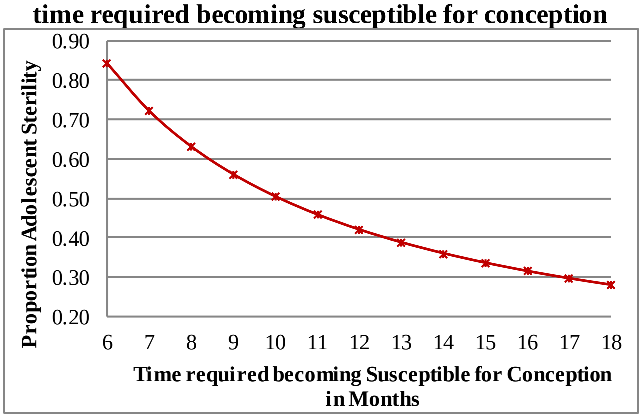
It is very clear that as fecundability is increasing the average and standard deviation of waiting time to first conception is decreasing for a particular value of adolescent sterility and time required becoming susceptible for conception. Also average and standard deviation of waiting time to first conception is increasing for increasing value of adolescent sterility and time required becoming susceptible for conception.

Table 3: Average and standard deviation of waiting time to first conception for various level of fecundability (λ), proportion of adolescent sterility (1-α) and time required becoming susceptible for conception

1-α	***t***	**λ=0.050**		**λ=0.055**		**λ=0.060**	
		Average	**SD**	**Average**	**SD**	**Average**	**SD**
0.15	6	25.10	20.11	23.28	18.31	21.77	16.80
	12	30.20	20.45	28.38	18.68	26.87	17.21
	18	35.30	21.01	33.48	19.28	31.97	17.86
0.30	6	24.20	20.19	22.38	18.39	20.87	16.89
	12	28.40	20.74	26.58	19.00	25.07	17.55
	18	32.60	21.63	30.78	19.97	29.27	18.60
0.45	6	23.30	20.22	21.48	18.43	19.97	16.93
	12	26.60	20.87	24.78	19.14	23.27	17.70
	18	29.90	21.91	28.08	20.27	26.57	18.92
0.60	6	22.40	20.21	20.58	18.42	19.07	16.92
	12	24.80	20.85	22.98	19.11	21.47	17.67
	18	27.20	21.86	25.38	20.21	23.87	18.86
0.75	6	21.50	20.17	19.68	18.37	18.17	16.87
	12	23.00	20.66	21.18	18.91	19.67	17.46
	18	24.50	21.47	22.68	19.78	21.17	18.40

Figure 1 shows the relationship between proportion of adolescent sterility and time required becoming susceptible for conception. It reveals that the proportion of adolescent sterility is inversely related to the time required becoming susceptible for conception.

Figure 1: Trend of proportion of adolescent sterility and time required becoming susceptible for conception



As the proportion of adolescent sterile female decreases their required time getting to be susceptible for conception increases. Some females conceive within the first month after marriage and the maximum waiting time is 120 months for the data considered, meaning individual fecundability varies from 0.008 to very close to 1. When the proportion of adolescent sterility in the population decreases, their level of fecundability shrinks towards the lower value and thus they take more time to conceive. Analysis of the present data indicates when *t* the time required becoming susceptible for conception is assumed as 6 months, the estimate of adolescent sterility is about 84 percent. When the assumed value of *t* is 18 months the proportion of adolescent sterile females is about 28 percent.

VI. Conclusion

The estimates of the parameters obtained by the proposed model represent the characteristic of females in the beginning of reproductive life. The salient feature of the suggested model is that it takes into account one of the important cause of delay in first conception, namely, adolescent sterility is a common phenomenon in the developing societies. It has been observed that fecundability is increasing however adolescent sterility is decreasing over the time. Also adolescent sterility and time required becoming susceptible for conception is influencing increasing the average and standard deviation of waiting time to first conception.

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