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ANALYSIS OF BIRTH INTERVALS IN A NON-CONTRACEPTING INDIAN POPULATION: AN EVOLUTIONARY ECOLOGICAL APPROACH

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Summary. Reproductive strategies are related to ecological constraints. This paper examines data on early birth spacing in a scheduled caste, Bengali-speaking, non-contracepting population of the Karimganj district of southern Assam, India, taking an evolutionary ecological perspective. It is found that on average birth intervals closed by boy–boy are longer than those closed by girl–girl. Birth spacing tends to be longer among upper-income and Craftsman sub-caste mothers. The presence of a 'grandmother' in the household shortens spacing. These findings are compatible with an evolutionary-based reproductive decision-making process.

Introduction

Natural patterns of human reproduction have been studied with respect to ecological factors that may have affected our hunter–gatherer ancestors. For example, energy constraints would have retricted nomadic hunters and gatherers to carrying only one child at a time, necessitating long birth intervals, so that the older child would have been able to walk relatively long distances on its own by the time its younger sibling was born (Short, 1994; Blurton-Jones, 1986). Thus, approaching the study of human fertility through evolutionary ecology can contribute to the understanding of the evolved mechanisms of energy investment that underlie differences in fertility (Blurton-Jones, 1989). Most of the relevant research on birth spacing patterns among married females in India has been carried out from a sociodemographic perspective (Nath *et al*., 1993, 1994, 1998; Nath & Land, 1994; Singh *et al*., 1993). No study analysing birth interval dynamics of an Indian population from an evolutionary ecological perspective has yet been reported.

The closed birth interval (CBI), which is the interval of time between two successive births, is a useful predictor of fertility. Henry (1956) showed that the fertility of a woman is inversely related to her mean closed birth interval. Rodriguez & Hobcraft (1980) demonstrated the greater sensitivity of birth interval analysis with respect to the timing of fertility compared with more conventional methods for studying fertility. The first birth interval (marriage to first birth) for Indian mothers is usually longer and erratic because of early marriage and other social customs and taboos acting through several sociodemographic factors (Nath *et al.*, 1993, 1998; Singh *et al.*, 1993). Later intervals, the second and third (between first and second, and second and third births), are considered here in order to explore how ecological factors affect natural fertility in a traditional Indian caste-dominated society.

Investment of costly energy in producing offspring is basic to reproductive or evolutionary success. Variation in resources and their allocation to reproduction is important in understanding differentials in measures of fertility. Many studies (Greenberg & White, 1967; Westoff *et al.*, 1961; Wyshak, 1969; Blanchard & Bogaert, 1997) report that birth intervals are longer following a male than a female child. The greater the cost of a child to the mother, and the longer the period over which that cost is extracted, the longer the birth interval should be. A few empirical studies demonstrate within-society differences in the attention, care and resource allocation to sons and daughters (Chen, Huq & D'Souza, 1981; Das Gupta, 1987; Miller, 1981). It has been hypothesized that parents provide better care for males than females when males have a reproductive advantage over females (Trivers & Willard, 1973). The amount of resources has been variably linked to fertility, both positively and negatively (Cronk, 1991; Vining, 1986) and thus birth intervals are expected to vary with income. In stratified Indian societies, birth intervals may also vary among different castes and sub-castes that occupy different ecological niches (Nath *et al.*, 1993, 1994; Singh *et al.*, 1993). Household composition is another factor that may influence birth interval length. A grandmother or other older woman genetically related to a childbearing woman's children may increase the younger woman's fertility through her energy contributions of labour and food production, thus enhancing her own inclusive fitness (Hawkes *et al.*, 1998). Thus, the birth intervals are predicted to be shorter in the presence of a 'grandmother' in the household.

In this paper, the lengths of second and third closed birth intervals in traditional Indian society are examined with respect to the effects of four socioecological correlates: (1) sexes of the consecutive sibs, (2) *per capita* monthly household income, (3) sub-caste, and (4) type of household (presence of 'grandmother' helper).

Materials and methods

Data and study population

Data for the research presented here come from the retrospective survey *A Study on Effects of Socio-Economic Factors on Fertility in the Scheduled Caste Population in the Rural Areas of Karimganj District, Assam*, conducted during 1988–89 (the reference date for survey questions was June 15, 1988). The survey was confined to the scheduled caste population: the socially and economically deprived class of the Indian population, lowest in the Hindu caste system. Membership in a caste is hereditary and is fixed for life. Educational attainment among these groups of people is very low, and most of them are still engaged in traditional occupations like agriculture, fishing, cloth washing, hair cutting, cane weaving and pot-making. Only a small number of persons are employed in government or non-traditional private sector jobs.

The Karimganj district of southern Assam is predominantly a Bengali-speaking area, where a large number of villages are identified as scheduled caste villages. If at least 10% of the village population belongs to the scheduled castes, the village is considered to be a scheduled caste village by the Directorate of Economics and Statistics, Assam. A sample of 37 scheduled caste villages was selected by simple random sampling. Then, all scheduled caste households were enumerated.

The survey comprises 1805 scheduled caste households from which reproductive histories of 2052 eligible women were collected. A woman was defined as eligible for the present study if both she and her husband were alive on the reference day of the survey and her age was less than 50 years. It is observed that only 1·5% of the couples practised some sort of modern contraception at some time during their married life. Only women in couples who did not practise any method of family planning to space and limit births were considered.

Explanatory variables and corresponding hypotheses

In the present analysis, the impacts of four independent socioecological variables on the duration of second and third birth intervals of mothers are examined. These covariates are: (1) sex of the consecutive sibs, (2) *per capita* monthly household income, (3) sub-caste, and (4) type of household.

In this rural Hindu society there is a preference for sons over daughters because of the Hindu belief that only a son can perform some the religious rites upon the deaths of his parents, and sons are considered heirs to their fathers' property and provide old-age security for the parents. Daughters require dowries at marriage and do not contribute to their natal family's welfare after marriage. Thus, sons receive better treatment than daughters (Das Gupta, 1987; Miller, 1981). Humans, like most mammals, have a polygynous evolutionary history reflected in physical dimorphism: males are larger than females, are carried slightly larger and longer *in utero*, nurse more vigorously and more frequently, and over all, are more expensive energetically to produce. The sex of offspring might thus be expected to influence women's reproductive capacity. Recent research (Low, 1991; Mace & Sear, 1997) indicates that the length of birth intervals is influenced by the sexes of the children born at the beginning and end of the birth interval. For the consecutive sibs of a closed birth interval four sequences of sexes are considered: (1) boy–boy, (2) boy–girl, (3) girl–boy, and (4) girl–girl. It is hypothesized that: (a) the longest closed birth interval should be boy–boy, and (b) the shortest closed birth interval should be girl–girl.

Fertility correlates with income in pre-demographic transition societies (Cronk, 1991). Vining (1986), however, shows evidence that in contemporary societies a negative correlation between socioeconomic status and fertility has developed. In the present study, monthly *per capita* income of the household may be considered as an indicator of economic status. On the basis of monthly *per capita* income (PCI), four economic groups were formulated for households within this generally low status community: (1) very low, PCI $\leq$ Rs 50, (2) low, Rs 51 $\leq$ PCI $\leq$ Rs 75, (3) middle, Rs 76 $\leq$ PCI $\leq$ Rs 100, and (4) upper, PCI $\geq$ Rs 101. Upward social striving

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through education is common now throughout the Indian population. It is expected, therefore, that despite their low social status, PCI would be negatively associated with levels of fertility. It is therefore hypothesized that PCI is positively associated with the length of the closed birth intervals.

Individuals within a population may experience different ecological positions within the environment; therefore reproductive strategies can vary between subgroups of a population (Low, 1993). Because the survey was restricted to the scheduled caste population, sub-castes were identified for the present analysis, each with a distinct social organization and culture. Sub-castes were (a) Namasudra: cultivators and bamboo basket-makers, (b) Kaibarta: fishermen, but also cultivators, and (c) Craftsman: barbers, washer-men, cobblers, earthen pot-makers and cultivators of small plots of land. In each of these sub-castes a few people were also employed in non-traditional jobs. It is hypothesized that sub-caste groups, reflecting their different cultural and ecological settings, will show distinct variation in closed birth interval distributions.

The influence of older generation women – grandmothers – on the reproductive success of younger generation women – daughters – who are either closely related to them or are wives of their sons has been hypothesized to be critical in the evolution of the human family as a food-sharing unit in which reproductive success or biologic fitness is enhanced (Hawkes *et al*., 1998). So critical is this relationship that it is hypothesized to explain the evolved post-menopausal extension of life span seen in our species, dubbed the 'grandmother hypothesis'. Through contributions to the energy needs of a younger woman producing offspring genetically related to the older woman, the latter can indirectly increase her own inclusive fitness at ages past the years of her own reproductive capacity (Hawkes *et al*., 1998). Grandmothering may affect infants in at least two ways: (a) by feeding nursing mothers and infants, thus accelerating the growth of infants; and (b) by providing food to weanlings and juveniles, thus allowing infants to be weaned earlier and helping to ensure their survival. In the present study, households were classified as follows: (a) without the presence of a grandmother or any senior woman who could play the role of a grandmother, or (b) with grandmother or other senior woman present. It is hypothesized that females living with a 'grandmother' helper are likely to experience shorter birth intervals.

Response variables and analytical methods

The analysis is restricted to ever-married women who had at least two live births. As the analysis requires the determination of the sex of the baby at the end of each birth interval, it did not consider right-censored observations. In addition, only birth intervals where the child that opened the birth interval survived for at least 12 months are included in this analysis to ensure some investment response from the mother and household.

Life table techniques are employed to estimate median second and third birth intervals for groups defined by the categories of the characteristics listed above. Two summary measures – median closed birth intervals and the proportions of mothers not having a closed birth interval by specified months – were calculated by standard life table techniques (Namboodiri & Suchindran, 1987). Univariate proportional hazards model analysis is used to measure the effect of each variable on the duration-specific probabilities of the length of the closed birth interval (hazards function) in the absence of controls for other variables. A non-parametric statistical procedure (the generalized Wilcoxon test) is used for group comparisons of these differences because some variables are not normally distributed. It tests for significant differences between the survival functions for various groups.

Because of the dependence of the length of the closed birth interval on many of the covariates studied, the use of conventional single-decrement life tables is not sufficient for the analysis. To investigate the partial effects of multiple factors on the timing of the second or third birth, multivariate hazards regression analysis was used to determine the net effects of each variable (Cox, 1972). The hazard function or instantaneous risk function at time t is given by

$$h(t;z) = h(t)\exp(\beta Z),$$

where $h(t;z)$ represents the instantaneous rate of having a second (third) birth at time t given that there is a first (second) birth for a married female with a vector of covariates Z; $h(t)$ is an arbitrary non-negative unspecified baseline hazard function not dependent on the covariate; β is a vector of unknown regression coefficients to be estimated. The hazard function allows estimation of the relative risks of women grouped by variable categories, with one group chosen as the reference group, by the exponent of the regression coefficient $\exp(\beta)$. Each exponentiated coefficient, $\exp(\beta)$, represents the effect of the covariate on the hazard function for a certain group. When there is no covariate present, the $\exp(\beta)$ term reduces to unity. Values greater than unity indicate that the relative risk of having a second (third) birth is greater (i.e. the birth interval is shorter) for this group compared with the reference group, whereas values less than unity indicate a decrease in the risk (i.e. the birth interval is longer).

Results

Table 1 presents a summary of the life table median second and third birth intervals and the proportion of mothers who failed to attain the next birth within 5 years following the first and second births. The overall median of the second birth interval for scheduled caste mothers is 29·2 months and that of the third birth interval is longer by 4·2 months. Broken down into groups by variable categories, the median birth interval lengths differ widely. The maximum median length for the second birth interval (35·7 months) is found in the Craftsman sub-caste. Mothers belonging to very low-income households have the minimum median length for the second birth interval (27·1 months). The maximum and minimum median lengths of the third birth interval correspond to the birth intervals closed by boy–boy (36·4 months) and girl–girl (31·9 months) sequences respectively.

For consecutive sexes of a sib pair, the longest median closed birth intervals for both second and third intervals were boy–boy and the shortest were girl–girl. For the second birth interval if the previous child was a boy, the median interval to the subsequent child was 33·0 months (boy) or 31·5 months (girl); if the previous child was a girl, the median interval to the subsequent child was 29·5 months (boy) or

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Table 1. Life table estimates of median birth intervals and proportions of mothers having no birth within 60 months by selected characteristics

Covariates	Median birth interval (months) between: 1st and 2nd	Median birth interval (months) between: 2nd and 3rd	Percentage not attaining next birth: After 1st birth	Percentage not attaining next birth: After 2nd birth
Overall	29·2	33·4	4·0	6·5
Sex of the consecutive sibs				
Boy–boy	33·0	36·4	5·6	6·0
Boy–girl	31·5	33·4	6·5	7·3
Girl–boy	29·5	32·4	2·9	6·8
Girl–girl	28·8	31·9	2·5	5·5
Per capita monthly household income				
≤Rs 50·00	27·1	32·9	3·4	4·5
Rs 51·00–Rs 75·00	28·1	32·3	2·8	5·0
Rs 76·00–Rs 100·00	29·5	34·8	4·2	6·2
≥Rs 101·00	30·3	34·1	5·9	10·5
Sub-caste				
Namasudra	29·1	34·0	4·5	6·9
Kaibarta	28·3	32·4	2·1	4·0
Craftsman	35·7	36·0	5·2	9·8
Type of household				
No grandmother	32·4	35·4	5·6	6·7
With grandmother	29·4	33·1	3·6	6·4

28·8 months (girl). A similar pattern of variation is observed in the durations of median third birth intervals.

As the level of income goes up, the lengths of the second and third birth intervals also increase, although only for the second interval is this response graded. With respect to sub-castes, a Kaibarta mother has the shortest closed birth intervals. A mother who reproduced with a ‘grandmother’ present in the household has a 3·0 (2·3) month shorter second (third) birth interval compared with mothers living with no ‘grandmother’ present. All four covariates under study are found to show a statistically significant difference between groups using the generalized Wilcoxon test (Table 2).

The proportions of mothers who failed to attain a subsequent birth within 60 months of the birth of the first child and/or the birth of second child also reveal differential timing of second and third birth intervals among the groups considered (Table 1). In this sample, only 2·1 to 6·5% of the mothers of first parity in the various groups failed to have their second birth within 60 months of their first birth. The corresponding percentages of mothers of second parity range from 4·0 to 10%. Of all mothers sampled 96 (93·5) % have their second (third) birth within 5 years of their first (second) birth.

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Table 2. Values of χ^2 based on the Wilcoxon log-rank test for comparison of groups

Groups	Second birth interval		Third birth interval	
	df	χ^2	df	χ^2
Sex of the consecutive sibs	3	14·1**	3	9·6*
Per capita monthly household income	3	9·6**	3	8·7*
Sub-caste	2	29·3**	2	6·5*
Type of household	1	7·2*	1	4·1*

*p<0·05; **p<0·01.

Table 3. Univariate hazards regression of the selected ecological covariates on the length of birth interval

Model	Birth interval between: 1st and 2nd birth			2nd and 3rd birth		
	− 2logL with covariates	Model χ^2	df	− 2logL with covariates	Model χ^2	df
Null	16,264·9	—	—	13,284·5	—	—
Sex of the consecutive sibs	16,252·5	12·4**	3	13,275·1	9·4*	3
Per capita monthly household income	16,256·9	9·1*	3	13,276·5	8·0*	3
Sub-caste	16,244·7	20·2**	2	13,277·6	6·9*	2
Type of household	16,259·7	4·2*	1	13,279·7	3·9*	1

*p<0·05; **p<0·01.

Univariate proportional hazards model analysis shows that all of the covariates have significant univariate relationships to the second and third birth interval dependent variable (Table 3). Ordered by reductions in chi-square relative to the null model (with only a constant term) accounted for by each explanatory variable from the largest to the smallest, the covariates can be arrayed as follows for the second birth interval: sub-caste, sex of the consecutive births, *per capita* monthly household income and type of household. For the third birth interval this order becomes: sex of the consecutive births, *per capita* monthly household income, sub-caste and the type of household.

A comparison of second and third birth intervals classified by specified covariates while controlling for other covariates is performed through multivariate hazards regression analysis and is presented in Table 4. This table provides the relative risk of the timing of the occurrence of the second and third birth, the net effects of the covariates on the hazards function, and the standard error of the hazards function for

Table 4. Multivariate hazards regression estimates of the effects of ecological covariates on the length of birth interval

Covariates	Birth interval between: 1st and 2nd births: Regression coefficient (β)	Exp (β)	SE	2nd and 3rd births: Regression coefficient (β)	Exp (β)	SE
Sex of the consecutive sibs						
Boy–boy	−0·274***	0·760	0·080	−0·210***	0·811	0·090
Boy–girl	−0·233***	0·792	0·077	−0·169*	0·844	0·085
Girl–boy	−0·159***	0·853	0·086	−0·111*	0·895	0·084
Girl–girl	a	a	a	a	a	a
Per capita monthly household income						
≤Rs 50·00	0·171*	1·186	0·083	0·187***	1·201	0·089
Rs 51·00–Rs 75·00	0·110**	1·116	0·077	0·140**	1·150	0·087
Rs 76·00–Rs 100·00	0·075	1·078	0·082	0·039	1·040	0·088
≥Rs 101·00	a	a	a	a	a	a
Sub-caste						
Namasudra	a	a	a	a	a	a
Kaibarta	0·172**	1·188	0·066	0·110**	1·116	0·073
Craftsman	−0·261***	0·770	0·089	−0·081*	0·922	0·099
Type of household						
No grandmother	a	a	a	a	a	a
With grandmother	0·111**	1·117	0·072	0·084*	1·087	0·086

**p*<0·1; ***p*<0·05; ****p*<0·01; a = reference category.

the four selected ecological factors. The results show that groups classified by consecutive sibs, *per capita* monthly household income, sub-caste, and type of household differ widely in their second and third birth intervals.

A second birth interval closed respectively by boy–boy, boy–girl and girl–boy is 24·0, 20·8 and 14·7% less likely to be shorter than that closed by girl–girl. A third birth interval closed by boy–boy, boy–girl and girl–boy is 18·9, 15·6 and 10·5% less likely to be shorter than that closed by girl–girl. The estimated relative risk of a shorter second birth interval is increased by 7·8, 11·6 and 18·6% for a mother belonging to middle, low and very low-income groups, respectively, compared with upper-income group mothers in this society. Corresponding increases in the relative risks for having a shorter third birth interval are 4·0, 15·0 and 20·1%. A Kaibarta mother in first parity is 18·8% more likely and a Craftsman mother is 23% less likely to have a shorter second birth interval as compared with a Namasudra mother. A similar trend of risk is observed by sub-caste for a mother in second parity to have a shorter third birth interval. A mother with a ‘grandmother’ present has an 11·7 (8·7) % greater risk of having a shorter second (third) birth interval as compared with one with no ‘grandmother’ present in the household.

Discussion

Within this non-contracepting population, birth interval lengths are shown to vary with socioecological conditions. This suggests that the decision-making of parents with respect to investing in children is sensitive to these conditions. Furthermore, they prefer to invest in those children who, under the family's particular living conditions, are likely to be successful, thus increasing their chances of maximizing future gene replication (Trivers & Willard, 1973). Variations in fertility rates within populations correlate with resource availability (see Betzig, 1996, for a review). Parental investment of time, energy or resources in the production or nurturing of one offspring can diminish a mother's ability to invest in older offspring or her ability to produce additional offspring in the future (Trivers, 1972).

Mace (1996) predicted that the cost of marrying a child has an important influence on the reproduction rates of parents. In this Indian society, the cost of marrying girls greatly exceeds the cost of marrying boys. Longer intervals following the birth of a male child may reflect Indian parent's preference for sons: parents who have just had a boy are more inclined to invest in that child than parents who have just had a girl, and they are therefore less eager to proceed to the next pregnancy. Further, it may be that boys are more difficult to raise than girls, so parents of boys require more time before they are ready to have another. The greater physiological costs of carrying and rearing boys are probably also reflected in boy–boy closed birth intervals. Thus, a male child delayed the timing of the next birth while a female child hastened the timing of the next birth.

The distribution of wealth has an impact on fertility rates. Rogers (1990) argued that the rich reproducing more slowly than the poor is not inconsistent with the hypothesis that reproductive strategies have been shaped by evolution. In the present study, it seems that an upper-income group family invests more in bearing and rearing their children through longer birth intervals, thus helping to ensure survivability and success of their offspring. As the levels of income decrease, the lengths of birth intervals decrease for mothers in this society. This society has a patrilineal inheritance system. Heritable resources provide an additional reason why parents may not like to maximize their reproduction rates leading to more children. Wealthier parents might have decided to produce a few relatively rich offspring whose resources would increase their probability of reproducing.

In a life table and multivariate analysis, Nath *et al*. (1993) and Singh *et al*. (1993) reported substantial variations in the duration of birth intervals among different castes and religious groups. In India today, especially among uneducated lower castes, occupational patterns are still determined by virtue of birth into a particular caste or sub-caste. For example, in this study population, the son of a Kaibarta father is supposed to follow fishing and fish selling, a type of free resource extraction, and birth intervals tend to be shorter compared with the other sub-castes studied. Slower transition to the next birth occurs among Craftsman females. This may reflect greater investment in their offspring as related to the expectation that sons will require more investment to train them in their fathers' particular skills. As most members of this sub-caste were either landless or small cultivators, their economic stability depends upon training their sons in the fathers' skills.

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Several evolutionary biologists (Gaulin, 1980; Hawkes *et al.*, 1989, 1997) have suggested that older females can use their energy to increase the reproductive success of their close relatives, thus increasing their own inclusive fitness. Among Hazda mothers of Tanzania higher fertility has been associated with compensating effects of older women's help (Hawkes *et al.*, 1997). The findings of the present study support the hypothesis that the contributions of 'grandmothers' would increase the reproductive success of childbearing women in the household. This hypothesis of course counters the idea that a family with no 'grandmother' present has greater privacy and thus has a wider scope for coital activity resulting in high fertility in a non-contracepting population.

More research would be needed to establish proximate mechanisms underlying the pattern of interval lengths associated with the sexes of sequential sib pairs. It would also be interesting to know how these variables affect human reproduction in different societal and ecological contexts in different traditional societies of India. Empirical data on parental and grandparental investment in offspring could contribute to a clearer understanding of the birth interval mechanisms. However, the significance of the impact of these four selected socioecological correlates has been shown for a non-contracepting traditional population in the present study.

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