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# Determining the Dynamics of Birth Interval Components: A Mathematical Model Based on Empirical Data from Manipur's Valley

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**Abstract:** Understanding the dynamics of birth interval components is crucial in high fertility populations. This study, conducted in Manipur's four valley districts, aimed to investigate the patterns of birth interval components among 977 eligible women using a cluster sampling scheme. From April 2022 to October 2022 with 1st April 2022 as the reference date, the data was gathered through a pre-tested semi-structured interview schedule. Cox's regression model was employed to analyze the impact of various factors such as infant mortality, lactation, contraceptive device usage, son preference, and religion on the birth interval components. The analysis revealed significant associations (P<0.01) between these factors and the dynamics of birth interval components in the censored data.

**Keywords:** Cox's model, censored data, infant mortality, lactation, son preference

## 1. Introduction

Human fertility is intricately tied to the duration of birth intervals (Bongaarts and Potter, 1983). These intervals, particularly closed birth intervals, consist of three primary components: postpartum amenorrhea (PPA), waiting time to conception, and gestation. While gestation remains constant, PPA varies in a complex manner, representing the interval between pregnancy termination and the onset of ovulation (Lantz et al., 1992; Nath et al., 1993; Clegg, 2001; Awang, 2003; Singh et al., 2012). The waiting time to conception, defined as the period from post-pregnancy menstruation to the initiation of the subsequent pregnancy, is heavily influenced by socio-economic, demographic, cultural, and behavioral factors (Kathleen et al., 1989; Lantz et al., 1992; Rao et al., 2006; Singh et al., 2007, 2011).

## 2. Literature Review:

In the majority of developing nations, nearly all women initiate breastfeeding for their offspring. Besides conferring immunological protection against prevalent childhood ailments such as allergies, diarrhea, and obesity (PIP, 2003), breastfeeding induces a transient state of infertility termed the postpartum non-susceptible period, during which ovulation is suppressed. Prolonged and intensive breastfeeding practices are correlated with extended periods of postpartum amenorrhea, especially in societies where breastfeeding is widespread (Srinivasan et al., 1989; Mukherjee et al., 1994; Dissanyake, 2000).

Bongaarts and Potter (1983) have elucidated that in populations lacking access to modern contraception, birth intervals are predominantly determined by the duration of breastfeeding. International consensus, echoed by Kennedy et al. (1989), asserts that breastfeeding provides over 98% protection against pregnancy within the first six months postpartum, contingent upon the mother engaging in exclusive or near-exclusive breastfeeding and experiencing no vaginal bleeding beyond the fifty-sixth day postpartum. The protracted duration of postpartum amenorrhea, particularly prevalent in rural areas, significantly contributes to the longer birth intervals observed among Indian women compared to their Western counterparts (Srinivasan et al., 1989; Nath et al., 1993; Dissanyake, 2000). While numerous studies have established a direct correlation between breastfeeding duration and postpartum amenorrhea, recent research has expanded our understanding by identifying additional socio-demographic factors that influence its duration (Nath et al., 1993; Mukherjee et al., 1994; Singh, 2007; Aryal, 2006; Singh et al., 2012; Azizi et al., 2020; Smith et al., 2021).

## 3. Objective:

The primary objective of this study is to empirically investigate the differential patterns of the duration of birth interval components, specifically postpartum amenorrhea (PPA) and waiting time to conception, concerning various socio-demographic factors of interest, aiming to address high fertility rates in India.

## 4. Materials and Methods:

A cross-sectional, community-based study was conducted in four valley districts of Manipur: Bishnupur, Imphal East, Imphal West, and Thoubal, which are located in the northeastern region of India bordering Myanmar. The study was carried out from April 2022 to October 2022 with 1st April 2022 as the reference date, utilizing a pre-tested and semi-structured interview schedule. A cluster sampling technique was employed, involving 1193 eligible women. Eligible participants were defined as women who had experienced at least two pregnancies in their lifetime, resulting in two live births. Given the nature of the data being censored and the aim to explore causal factors, survival analysis techniques, particularly Cox's regression analysis, were conducted using SPSS vs 27. The results were expressed in terms of the p-value of the Wald test of the regression coefficients (p), relative risk (RR) of the explanatory variables with a 95% confidence interval (CI).

**Cox's Regression Model**

The Cox's regression model employed in this study is represented by the formula $h(t, Z) = h_o(t)f(Z)$, where $h_o(t)$ represents the baseline failure rate or typical hazard, and $f(Z)$ is a parametric link function incorporating the covariates. The commonly used form of $f(Z)$ is $\exp(\beta, Z)$, known as the 'log-linear form.' Thus, for an individual with covariate vector Z, the hazard function $h(t, Z)$ can be expressed as $h(t, Z) = h_o(t)\exp(\beta, Z)$, indicating the relative risk of failure.

The response variables under consideration are the components of birth intervals, namely the duration of PPA and waiting time to conception, restricted to the last births to minimize data recall error. Variable specification includes a range of socio-demographic factors such as age at menarche, age at marriage of husband and wife, age at delivery, parity, infant mortality (dead=1, alive=0), number of living sons and daughters, duration of marriage, couple's desired number of sons, sex of the previous child (male=1, female=0), type of feeding (completely breast fed=1, otherwise=0), lactation (duration of breast feeding in month), use of contraceptives (effectively used=1, otherwise=0), educational level of husband and wife (completed years in education), religious affiliation (concerned=1, Others=0), and family monthly income.

## 5. Analysis and Results:

Upon adjusting for the effects of other explanatory variables, only three factors were found to have significant impacts on the variation of postpartum amenorrhea (PPA): duration of breastfeeding ($p < 0.01$), infant mortality ($p < 0.01$), and family income ($p < 0.05$) (See Table - 1). Utilizing the stepwise method of Cox regression analysis, the most influential factors contributing to a higher risk of shorter PPA were investigated, revealing five determinants in the final model (Table - 2): infant mortality, family income, lactation, type of feeding, and Islamic religion. In the first step, lactation demonstrated a significant impact on PPA dynamics ($p < 0.01$), with a 12% reduced risk of shorter PPA observed when mothers practiced breastfeeding for six months (RR = 0.98, 95% CI: 0.98-0.99). Following lactation, infant mortality emerged as a high-risk factor in the second step ($p < 0.01$, RR = 2.13, 95% CI: 1.44-3.14). Additionally, family income ($p < 0.01$), Islamic religion ($p < 0.05$), and type of feeding ($p < 0.05$) gradually revealed themselves as high-risk indicators of PPA in subsequent steps.

Similarly, for waiting time to conception, five significant factors were identified after adjusting for other variables (Table - 1): death of previous child in infancy ($p < 0.01$), sex of previous child ($p < 0.05$), couple's desire number of sons ($p < 0.05$), lactation ($p < 0.01$), and educational level of wife ($p < 0.05$). Through the stepwise method, six factors influencing waiting time to conception were confirmed in the final model (Table 2): death of previous child in infancy, sex of previous child, couple's desire number of sons, use of contraceptive device, lactation, and Hindu religion. Lactation demonstrated a notable impact on both PPA and waiting time to conception, with a reduction in the risk of shorter durations observed with increasing breastfeeding duration. Conversely, infant mortality was associated with shorter PPA and waiting time to conception. Religious affiliation, particularly Islam, was linked to shorter PPA durations, while Hinduism was associated with longer waiting times to conception.

## 6. Discussion:

The findings of this study reaffirm the role of lactation in prolonging postpartum amenorrhea. This physiological mechanism is thought to involve the hypothalamic-pituitary-gonadal axis, where breastfeeding inhibits the release of gonadotropin-releasing hormone (GnRH), subsequently suppressing ovulation. The influence of lactation on birth intervals has been supported by previous studies (Srinivasan et al., 1989; Nath et al., 1993; Dissanyake, 2000; Singh, 2010; Singh et al., 2012). Infant mortality was found to limit the duration of postpartum amenorrhea indirectly, possibly through its association with lactation practices. Additionally, higher family income levels were associated with shorter PPAs, likely influenced by educational attainment and access to healthcare. Religious differences, particularly among Islam women, were noted to impact the duration of PPA, potentially due to nutritional disparities. In terms of waiting time to conception, factors such as the death of previous children in infancy and son preference significantly influenced shorter durations. Lactation was found to prolong the waiting time, possibly due to associated lifestyle and socioeconomic factors. Hindu religion was associated with longer waiting times, contrasting with Islam, which exhibited shorter durations.

## 7. Conclusion:

The dynamics of postpartum amenorrhea and waiting time to conception significantly contribute to fertility regulation through birth intervals. Factors such as infant mortality, lactation, and religious affiliation were found to have significant impacts on both duration variables. Additionally, family income, type of feeding, son preference, and contraceptive use were identified as significant factors influencing waiting time to conception. These findings emphasise the significance of socio-demographic factors in regulating birth intervals, highlighting the need for comprehensive interventions to address high fertility rates. Further research on a larger scale covering a wider geographical area is recommended to better understand the causal effects on birth interval components and mitigate high fertility levels effectively.

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Table-1: Cox' Regression analysis (adjusted) on birth interval components

| Covariates | PPA | | Waiting time to conception | |
|---|---|---|---|---|
| | RR(95%CI) | P-value | RR(95%CI) | P-value |
| Age at menarche | 0.97 (0.92-1.01) | >0.05 | NC | |
| Age at marriage of wife | 1.03 (0.99-1.07) | >0.05 | 1.06 (0.97-1.15) | >0.05 |
| Age at marriage of husband | 0.99 (0.97-1.01) | >0.05 | 1.01 (0.99-1.03) | >0.05 |
| Age at delivery | 0.99 (0.95-1.02) | >0.05 | 0.96 (0.88-1.04) | >0.05 |
| Parity | 1.04 (0.86-1.26) | >0.05 | 0.93 (0.78-1.11) | >0.05 |
| No. of living son | 0.90 (0.76-1.07) | >0.05 | 1.12 (0.92-1.37) | >0.05 |
| No. of living daughter | 0.94 (0.79-1.13) | >0.05 | 1.08 (0.89-1.31) | >0.05 |
| Sex of the previous child | 1.01 (0.85-1.21) | >0.05 | 1.26 (1.06-1.50) | <0.05 |
| Death of previous child | 2.07 (1.36-3.17) | <0.01 | 2.67 (1.66-4.30) | <0.01 |
| Duration of marriage | NC | | 1.05 (0.97-1.14) | >0.05 |
| Type of feeding | 0.85 (0.70-1.02) | >0.05 | 1.02 (0.83-1.25) | >0.05 |
| Lactation | 0.98 (0.97-1.00) | <0.01 | 0.97 (0.96-0.97) | <0.01 |
| Use of contraceptives | NC | | 1.17 (0.99-1.37) | >0.05 |
| Religion due to to Hindu | 0.99 (0.84-1.17) | >0.05 | 0.83 (0.68-1.01) | >0.05 |
| Religion due to to Islam | 1.34 (0.99-1.82) | >0.05 | 1.12 (0.82-1.52) | >0.05 |
| Educational level of wife | 0.99 (0.97-1.01) | >0.05 | 1.02 (1.00-1.04) | <0.05 |
| Educational level of husband | 1.01 (0.99-1.04) | >0.05 | 0.99 (0.97-1.02) | >0.05 |
| Family monthly income | 1.01 (1.00-1.02) | <0.05 | 0.99 (0.98-1.00) | >0.05 |
| Couple's desire No. of son | 1.17 (0.94-1.46) | >0.05 | 1.32 (1.04-1.67) | <0.05 |

NC - Not considered

Table-2: Cox' Regression analysis (stepwise) on birth interval components

| **Step** | PPA | | | Waiting time to conception | | |
|---|---|---|---|---|---|---|
| | Covariates | RR(95%CI) | P-value | Covariates | RR(95%CI) | P-value |
| 1 | Lactation | 0.98 (0.98-0.99) | <0.01 | Lactation | 0.97 (0.97-0.98) | <0.01 |
| 2 | Death of previous child | 2.13 (1.44-3.14) | <0.01 | Death of previous child | 2.63 (1.68-4.12) | <0.01 |
| | Lactation | 0.98 (0.98-0.99) | <0.01 | Lactation | 0.97 (0.96-0.97) | <0.01 |
| 3 | Death of previous child | 2.15 (1.46-3.18) | <0.01 | Death of previous child | 2.65 (1.69-4.15) | <0.01 |
| | Lactation | 0.98 (0.98-0.99) | <0.01 | Lactation | 0.97 (0.96-0.97) | <0.01 |
| | Family income | 1.01 (1.00-1.01) | <0.01 | Religion due to Hindu | 0.81 (0.70-0.94) | <0.01 |
| 4 | Death of previous child | 2.13 (1.44-3.14) | <0.01 | Death of previous child | 2.56 (1.64-4.02) | <0.01 |
| | Lactation | 0.98 (0.98-0.99) | <0.01 | Sex of previous child | 1.22 (1.05-1.41) | <0.01 |
| | Family income | 1.01 (1.00-1.01) | <0.01 | Lactation | 0.97 (0.96-0.97) | <0.01 |
| | Religion due to Islam | 1.37 (1.05-1.79) | <0.05 | Religion due to Hindu | 0.80 (0.69-0.93) | <0.01 |
| 5 | Death of previous child | 2.14 (1.45-3.16) | <0.01 | Death of previous child | 2.49 (1.59-3.91) | <0.01 |
| | Lactation | 0.98 (0.98-0.99) | <0.01 | Sex of previous child | 1.25 (1.08-1.45) | <0.01 |
| | Family income | 1.01 (1.00-1.01) | <0.05 | Desire No. of son | 1.27 (1.03-1.57) | <0.05 |
| | Religion due to Islam | 1.37 (1.05-1.78) | <0.01 | Lactation | 0.97 (0.96-0.97) | <0.01 |
| | Type of feeding | 0.83 (0.69-0.99) | <0.05 | Religion due to Hindu | 0.81 (0.70-0.94) | <0.01 |
| | Not found | | | Death of previous child | 2.51 (1.60-3.93) | <0.01 |

| | | | | |
|---|---|---|---|---|
| 6 | | Sex of previous child | 1.25 (1.08-1.45) | <0.01 |
| | | Desire No. of son | 1.29 (1.05-1.58) | <0.05 |
| | | Use of contraceptives | 1.17 (1.00-1.36) | <0.05 |
| | | Lactation | 0.97 (0.96-0.97) | <0.01 |
| | | Religion due to Hindu | 0.81 (0.70-0.95) | <0.01 |