Discrepancies of recurrent birth intervals using longitudinal data analysis in Ethiopia: interim EDHS 2019

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ABSTRACT

Objective This study aimed to determine whether the birth interval changes differently over time among women in Ethiopia and whether the change depends on women, children and household characteristics measured at the last visit.

Methods Longitudinal study design was implemented based on the data obtained from the 2019 Ethiopia Mini Demographic and Health Survey consisting of a total of 3630 mothers. Generalised estimating equation and generalised linear mixed model were employed to estimate the effect of the determinants given the correlation between birth intervals within a mother is under consideration.

Results The majority of women were Muslims (48.1%) and come from rural areas (82.2%). About 77.2% of women at first birth were below 20 years old. A significant correlation (p-value <0.0001) between the first and second birth intervals of mothers was observed. The estimated birth interval of women from the poorest household was 0.877 (e−0.1317) times the estimated birth intervals of women from the richest household. This indicates richest households were likely to have higher birth intervals as compared with the poorest households (95% CI e−0.1754=0.839 to e−0.088=0.916).

Conclusion The birth intervals of over one-fifth of mothers were 1 year, less than the birth interval recommended by the WHO standard. It was also perceived that successive birth intervals are correlated. Mothers who have delivered female children had lower birth intervals than mothers who have delivered male children. As compared with the birth intervals of mothers from a household with higher economic status, the birth intervals of mothers from a household with lower economic status had lower birth intervals. In this study, significant effects of religion, contraceptive use, region, mothers' current age, education level and mothers' current marital status on birth intervals were also noted.

BACKGROUND

Birth interval is the difference between the birth date of a child and the birth date of preceding children in months or years. It is a determinant of parental investments in children and the rate of fertility. According to the WHO, the recommended birth interval between the last live birth and the subsequent live birth is 33 months. A shorter birth interval has adverse effects on the child and the mother. Especially, for under-five children, it is responsible to be stunted, underweight or wasted. The fertility rate of the population is increasing with the increasing rate. Among numerous factors, the birth interval between successive children within the family has a substantial effect on the fertility rate.

A shorter birth interval implies a higher fertility rate and vice versa for longer birth intervals. Globally, as compared with developed countries, the prevalence of short birth intervals is higher in low-income and middle-income countries such as Africa and Asia. In Africa next to Nigeria, Ethiopia is the most populous country. In low-income and middle-income countries and Ethiopia, in particular, the majority of women are practiced shorter birth interval lengths than they would prefer. This is predominantly because most women lack of habit using contraception after birth and therefore are likely to become pregnant once fecundity returns. This also points to a statistically significant difference between the actual and preferred

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study used longitudinal data analysis approaches, which improve the accuracy of the data to assess the change in birth interval over time.
⇒ In this study, the data were obtained from 2019 Ethiopia Mini Demographic and Health Survey, aimed to provide up-to-date estimates of key demographic and health indicators.
⇒ The outcome of interest was birth interval (in years) that computed using the difference between successive years of birth.
⇒ To detect the distribution of the data considered in this study several types of distributions were evaluated using a histogram curve.
⇒ Since the dataset used in this study is incomplete, not all characteristics of children, mothers and households were taken into account.

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Numerous studies have demonstrated that birth intervals are influenced by socioeconomic, demographic, biological and behavioural factors. According to a report based on the traditional African population, the sex of children in the subsequent birth has a significant effect on birth intervals. For instance, a birth interval after the birth of a girl is significantly lower than after the birth of a boy which shows lower parental investments in girls. On the other hand, this also indicates that the birth interval of women with no son was shorter than for those with at least one son. A study conducted in Malaysia, Philippines and Indonesia indicate that breast feeding behaviour and contraceptive use are the main factors that enable to explain the size of the birth interval. A study conducted in southern Ethiopia also shows the economic status of women has an effect in which women with higher economic status had a higher likelihood to have short birth intervals than those with lower economic status. It is also indicated that women’s birth intervals were different based on the residential areas in which urban women were less likely to have short birth intervals than rural women.

According to a study based on the 2019 Ethiopian Mini Demographic and Health Survey, the median birth interval length of women was 2 years. In regards to women’s age, this study also reported that younger women had shorter birth intervals than older women. The risk factors such as age at marriage of mothers, duration of breast feeding and place of residence are contributing to the birth interval. Likewise, the studies show that sex composition has a substantial effect on the birth interval in which the more sons women had, the more likely they were to have higher birth interval length and use contraception. Women who have children of both sexes have the longest birth intervals while women who have only daughters have the shortest birth intervals as they are eager to get a son for the subsequent pregnancy.

A systematic mixed study on low-income and middle-income countries reported that socioeconomic level, mothers’ current age and education level have significantly associated with birth intervals. Though, both too short and long birth intervals lead to adverse parental and child health outcomes, too short birth intervals may lead to worse health problems as women faced a lack of time to recover from a previous pregnancy and invest in children.

The statistical approaches that most of the studies implemented on birth intervals so far were cross-sectional. Thus, little attention is given to the progress of birth intervals through time using longitudinal analysis and enabling assessment of the effect of other covariates. For economic development having adequate human resources is essential and has a predominant contribution over other determinants. However, this is feasible when the fertility rate of women is as parallel as the economic development of a country. If this is not the case understanding and practicing how to manage birth intervals in various methods such as contraceptive use are the best alternatives. This leads the household within the country to invest in all parental care sufficiently. Therefore, beyond determining the factors associated with birth intervals through cross-sectional study design, it is more advantageous to visualise birth intervals using longitudinal study design and detecting the most important factors for better policy and decision making as there is a statistically significant link between birth intervals and maternal as well as child health. Thus, this study aimed to determine whether the birth interval changes differently over time among women in Ethiopia and whether the change depends on women, children and household characteristics measured at the last visit.

**METHODS**

**Data source**

In this study, a total of 3558 mothers obtained from the 2019 Ethiopia Mini Demographic and Health Survey (EMDHS) were involved. This secondary data were downloaded from the DHS website (www.dhsprogram.com). Providing up-to-date estimates of key demographic and health indicators by collecting high-quality data for maternal and child health are the primary objectives of EDHS among its multidisciplinary objectives. The sampling frame used for the 2019 EMDHS is a frame of all census enumeration areas (EAs) created for the 2019 Ethiopia Population and Housing Census and conducted by the Central Statistical Agency. The 2019 EDHS sample was stratified and selected in two stages. In the first stage, a total of 305 EAs were selected with probability proportional to EA size and with independent selection in each sampling stratum. A household listing operation was carried out in all selected EAs from January through April 2019. The resulting lists of households served as a sampling frame for the selection of households in the second stage. In the second stage of selection, a fixed number of 30 households per cluster were selected with an equal probability of systematic selection from the newly created household listing, and maternal as well as children characteristics were obtained via interview and questionnaire.

**Inclusion/exclusion criteria**

The study included mothers who completed pertinent forms requesting personal information and had at least two birth intervals. Hence, mothers who did not complete all relevant information or had birth intervals below one were excluded.

**Variables**

**Dependent variable**

The dependent variable was birth interval (in years) for successive birth delivery of mothers. It is computed using the difference between successive years of birth delivery. The birth interval is the time difference
between successive births of a mother, see figure 1. A total of 14,675 birth interval observations were obtained from 3,558 mothers. From each mother at least two successive birth intervals were recorded.

**Independent variables**
The independent variables of this study were the socio-economic, demographic and biological variables adopted from previous studies. A brief description of the independent variables was described in table 1.

**Statistical analysis**
As the statistical approach employed in a study depends on the distribution of the data. To detect the distribution of the data considered in this study several types of distributions were evaluated using a histogram curve (see figure 2). Pinpointing the probability distribution that the research data follow is critical for analyses that model with a log link function is given by:

\[
\mu_{ij} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p
\]

(1)

Where \(\mu_{ij}\) is the average birth interval measured (in years) of the \(i\)-th mother at the \(j\)-th birth interval. \(i=1, 2, 3, \ldots, 3558\) and \(j=1, 2, 3, \ldots, 10\). This is because the number of mothers considered in this study was 3,558 and a mother with maximum deliveries was 11. Note that, if a mother has births \(k\) times, then the number of birth interval measured become \(k-1\), see figure 1.

The GEEs approach is a widely used estimation method for longitudinal marginal models. The within-subject correlations among the repeated measures are taken into account by using a working correlation structure and employing that structure for the parameter estimations. Due to the marginal mean function, GEE does not make any full distributional assumptions. The SAS software provides two procedures that enable to performance of GEE analysis. These are the GENMOD procedure and the GEE procedure and hence the two procedures were implemented. In the case of GEE, the working correlation matrix does not have to be the true correlation matrix for the estimated parameters to be consistent.

**Generalised linear mixed model**
Unlike GEE, which accounts for correlated responses at the estimation stage, the GLMM tackles this problem up-front by explicitly modelling such a dependence structure by using random effects. Multiple measurements per mother generally result in correlated errors that are explicitly forbidden by the assumptions of standard Gamma regression models. Because of this, using GLMM was a preferred method to include a random effect in the model while taking into account correlation to obtain an accurate estimation of the fixed effects. The GEE approach of the Gamma regression model can consider repeated measurements but cannot consider the random effects. Therefore, the statistical model of the GLMM can be given by:

\[
\log (\mu_{ij}) = \beta_0 + \beta_{oi} + \beta_{iTime} + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p
\]

(2)

The most common SAS procedure, GLIMMIX, was used for inference. The data organisation and summary statistics were done using SPSS V.25 software while other statistical analyses were done using SAS software.

**RESULTS**
For each of the variables taken into account in this study, a description, summary statistics and frequency distribution were provided in table 1. The majority of women were Muslims religion (48.1%) and come from rural areas (82.2%). The sex of over three-fourths of household heads (77.7%) was male while over nine-tenths of women (91.1%) were currently married. Most of the women (32.5%) were from a household with the poorest wealth index and practiced contraceptive use (76.1%). About 59.1% of women were from a household who do not have an improved water source. The age of the majority of women (77.2%) at first birth was below 20 years old. The
## Table 1  Independent variables description, frequency distribution and summary statistics

| Variables                        | Categories (codes) | Frequency | Per cent |
|----------------------------------|-------------------|-----------|----------|
| Residence                        | Urban (1)         | 630       | 17.8     |
|                                  | Rural (2)         | 2928      | 82.2     |
| Religion                         | Orthodox (1)      | 1010      | 28.4     |
|                                  | Protestant (2)    | 754       | 21.2     |
|                                  | Muslim (3)        | 1713      | 48.1     |
|                                  | Others            | 81        | 2.3      |
| Mothers marital status           | Divorced          | 167       | 4.7      |
|                                  | Married (1)       | 3241      | 91.1     |
|                                  | Widowed (2)       | 150       | 4.2      |
| Region                           | Tigray (1)        | 269       | 7.6      |
|                                  | Afar (2)          | 298       | 8.4      |
|                                  | Amhara (3)        | 385       | 10.8     |
|                                  | Oromia (4)        | 530       | 14.9     |
|                                  | Somalie (5)       | 378       | 10.6     |
|                                  | Benishangul (6)   | 342       | 9.6      |
|                                  | SNNPR (7)         | 523       | 14.7     |
|                                  | Gambela (8)       | 298       | 8.4      |
|                                  | Harari (9)        | 234       | 6.6      |
|                                  | Addis Ababa (10)  | 69        | 1.9      |
|                                  | Dire Dawa (11)    | 232       | 6.5      |
| Sex of household head            | male (1)          | 2765      | 77.7     |
|                                  | female (2)        | 793       | 22.3     |
| Contraceptive use                | No (0)            | 850       | 23.9     |
|                                  | Yes (1)           | 2708      | 76.1     |
| Wealth index                     | Poorest (1)       | 1158      | 32.5     |
|                                  | Poorer (2)        | 695       | 19.5     |
|                                  | Middle (3)        | 625       | 17.6     |
|                                  | Rich (4)          | 588       | 16.5     |
|                                  | Richest (5)       | 492       | 13.8     |
| Mothers age at first birth       | <20 (0)           | 2745      | 77.2     |
|                                  | 20–34 (1)         | 809       | 22.7     |
|                                  | 35–49 (2)         | 4         | 0.1      |
| Household education level        | No education (0)  | 2687      | 75.5     |
|                                  | Primary (1)       | 730       | 20.5     |
|                                  | Secondary and above (2) | 141 | 4.0 |
| Household size                   | 1–4 (small) (0)   | 412       | 11.6     |
|                                  | 5–9 (medium) (1)  | 2802      | 78.8     |
|                                  | 10 and more (large) (2) | 344 | 9.7 |
| Water source                     | Unimproved (0)    | 1455      | 40.9     |
|                                  | Improved (1)      | 2103      | 59.1     |
| Mothers current age              | <21 (0)           | 17        | 0.5      |
|                                  | 20–34 (1)         | 1369      | 37.5     |
|                                  | 35–49 (2)         | 2243      | 63.0     |
average birth interval was 2.87 years with an average deviation of 1.828 years.

The birth interval and its summary statistics were revealed in table 2. The 1st, 2nd, ..., 10th indicate the occurrence of the birth interval sequence of mothers at the first time, the second time, ... and the tenth time, respectively. This was also explained in figure 1. The average, minimum and maximum first birth intervals of mothers were 2.86, 1.00 and 9 years, respectively. The average birth interval had a decreasing trend from 3.06 to 2.43 years.

The birth intervals or gaps (in years) frequency distribution was presented using a histogram (see table 2). Numerous mothers have experienced birth intervals of 2 years.

The scatter correlation matrix between 10 consecutive birth intervals was presented in figure 3. The correlation matrix's p value directly below the diagonal shows how significantly the correlation between subsequent birth intervals deviates from zero. The p value less than 0.05 indicates there is a significant correlation between corresponding birth intervals. For instance, the correlation between first and second birth intervals was significantly different from zero (p value < 0.0001). Likewise, the second birth interval correlates significantly different from zero with the third, fourth and fifth birth intervals of mothers. The correlation between birth intervals decreases as the time of birth are far apart.

The profile plot for a sample of 120 randomly selected mothers was revealed in figure 4. The overall average birth interval had a slightly decreasing trend throughout time (see also table 2). This might be because the mothers are rushing to have more children before their fertility time for pregnancy is stopped.

| Table 2 Birth interval sequence and its summary statistics |
|-----------------------------------------------------------|
| Birth interval | 1st  | 2nd  | 3rd  | 4th  | 5th  | 6th  | 7th  | 8th  | 9th  | 10th |
| Frequency      | 3630 | 3599 | 2753 | 2045 | 1454 | 953  | 564  | 322  | 170  | 91   |
| Mean           | 2.86 | 3.06 | 2.87 | 2.86 | 2.76 | 2.72 | 2.71 | 2.52 | 2.51 | 2.43 |
| SD             | 1.80 | 2.01 | 1.86 | 1.83 | 1.66 | 1.64 | 1.68 | 1.39 | 1.35 | 1.31 |
| Minimum (in years) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Maximum (in years) | 9.00 | 9.00 | 9.00 | 10.00 | 6.00 | 5.00 | 7.00 | 4.00 | 5.00 | 4.00 |

Parameter estimation

The estimated effects of socioeconomic, demographic, biological and behavioural characteristics of mothers and households on birth intervals were done using a GEE and GLMM approaches of Gamma distribution (see table 4). The Gamma regression model obtained using GEE was compared based on different working correlations such as independent, compound symmetry and autoregressive. The comparison was done using quasi information criterion (QIC). In this regard, the QIC of the GEE approach of the Gamma regression model for independent, compound symmetry and autoregressive were 877, 312 and 771, respectively. Thus, as the QIC of compound symmetry working correlation is minimum, considering compound symmetry working correlation of GEE is better. Even when the specified working correlation assumption is wrong, it is still possible to make inferences based on empirically corrected estimates as the estimates are consistent and robust.

The 95% CI of the estimated effects of a covariate includes zero indicating it is significantly associated with the estimated birth intervals. On the other hand, the exponent of the 95% CI of the estimated effects of the covariates includes one indicating the covariates were significantly associated with the estimated birth intervals. Thus, household religion, wealth index, contraceptive use, religion, household size, education level, mother’s current marital status and mothers’ current age had a significant effect on birth interval. The estimated birth interval of women from the richest household was 0.877 (e−0.1317) times the estimated birth intervals of women from the richest household. This indicates that the birth intervals of women from the poorest households were lower by 12.3% than the birth intervals of women from the richest households. On the other hand, this implies richest households were more likely to have higher birth intervals as compared with the poorest households (95% CI e−0.1754=0.839 to e−0.088=0.916).

In regards to household head education level, the women’s birth intervals were substantially different. The estimated birth interval of women from the illiterate household was 0.885 (e−0.1226) times the estimated birth intervals of women from a household with secondary and above education level (95% CI e−0.1098=0.844 to e−0.0734=0.927). This implies the birth intervals of mothers from illiterate households were lower by 11.5% than the birth intervals of mothers from a household with secondary and above education level.
Table 3  Birth interval sequence and its summary statistics

| Birth interval (in years) | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | Total |
|--------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| Frequency                | 2998| 4555| 3263| 1653| 914 | 545 | 332 | 212 | 124 | 79  | 14675 |
| Per cent                 | 20.40| 31.06| 22.24| 11.26| 6.19| 3.712| 2.26| 1.44| 0.84| 0.54| 100.00 |

secondary and above education levels. Thus, mothers from educated households were more likely to have higher birth intervals than mothers from non-educated households. Mothers who have not used contraceptives (95% CI $e^{-0.0786}=0.924$ to $e^{-0.0754}=0.969$) were less likely to have a higher birth interval. Whereas mothers from small households (1–4) (95% CI $e^{0.1698}=0.844$ to $e^{-0.0754}=0.927$) and medium households (5–9) (95% CI $e^{0.1698}=0.844$ to $e^{-0.0754}=0.927$) were more likely to have higher birth intervals as compared with mothers from large household (10 and above). The estimated birth interval for married mothers was $1.079 (e^{0.0.0756})$ times the estimated birth intervals of widowed mothers (95% CI $e^{0.0228}=1.023$ to $e^{0.1285}=1.137$). The estimated exchangeable correlation between birth intervals at each period of birth was 0.020 which was significantly different from zero ($p$ value <0.05).

To incorporate the random effects the conditional Gamma regression model (GLMM) was employed, see figure 4. The model with random effects indicates a model includes random intercept and/or random slopes. The model demonstrates that the baseline birth intervals of mothers were different (random intercept, $\sigma^2=0.060$). Whereas the trends of birth intervals across mothers (random slope) over time were not substantially different which is supported by the information revealed from the profile plot in figure 4. Likewise, the GEE approach, region, household’s religion, wealth index, contraceptive use, household size, education level and mothers’ current marital status had a significant effect on the birth interval in the GLMM approach. The intercept variance of birth intervals of mothers is estimated at square root (0.060) which is significantly different from zero. Thus, the estimated SD is equal to 0.245 (0.060). This tells that the birth intervals of mothers at their first birth were deviated by 0.245 years from the average.

**DISCUSSION**

This study attempted to demonstrate the progress of birth intervals of the mother over time and associated socio-economic, demographic, behavioural and biological factors based on data obtained from 2019 EMDHS. Women who have delivered more than two children were asked about the birth interval, the outcome of interest. The birth interval (in years) was computed as the time difference between successive births of mothers. The prevalence of mothers who have shorter birth intervals was higher which violates the birth interval recommended by WHO standards. It was also perceived that successive birth intervals correlate. In this study, significant effects of religion, contraceptive use, region, mothers’ current age, education level and mothers’ current marital status on birth intervals were also identified. With more than one measured birth interval for each mother, assuming each measured birth interval as independent will end up erroneous. Thus, employing a statistical model which does not assume the correlation between birth intervals among mothers will not be effective. As a result, statistical approaches that enable to account for the correlation between birth interval within a mother such as GEE and GLMM were employed.14 15

**Figure 3** Scatter correlation matrix of 10 successive birth intervals.

**Figure 4** A profile plot for a sample of 120 sample mothers’ birth intervals.
## Table 4  Parameter estimates independent variables using GEE and GLMM approaches

| Variables          | Levels        | Est (SE)       | 95% CI                | Est (SE)       | 95% CI                |
|--------------------|---------------|----------------|-----------------------|----------------|-----------------------|
| **Approaches**     |               | GEE            | GLMM                  | GEE            | GLMM                  |
| **Region**         |               |                |                       |                |                       |
| Addis Adaba        |               | 0.0214 (0.0381)| (−0.0533 to 0.0962)   | 0.02214 (0.03973)| (−0.05574 to 0.10)   |
| Afar               |               | −0.0812 (0.0302)| (−0.1403 to −0.0221) | −0.0818 (0.0313)| (−0.1431 to −0.02045) |
| Amhara             |               | 0.0348 (0.0218)| (−0.0079 to 0.0776)   | 0.0363 (0.02289)| (−0.00856 to 0.08116) |
| Benishangul        |               | −0.0221 (0.0248)| (−0.0707 to 0.0266)   | −0.02131 (0.02593)| (−0.07214 to 0.02951) |
| Dire Dawa          |               | −0.1362 (0.0304)| (−0.1958 to −0.0766)  | −0.137 (0.03157)| (−0.1989 to −0.07511) |
| Gambela            |               | 0.0462 (0.0269)| (−0.0065 to 0.0989)   | 0.04717 (0.02808)| (−0.00787 to 0.1022) |
| Harari             |               | −0.0813 (0.0296)| (−0.1392 to −0.0233)  | −0.08279 (0.03075)| (−0.1431 to −0.02252) |
| Oromia             |               | −0.0936 (0.0246)| (−0.1418 to −0.0455)  | −0.0948 (0.02564)| (−0.1451 to −0.04454) |
| SNNPR              |               | −0.058 (0.0248)| (−0.1066 to −0.0094)  | −0.05811 (0.02594)| (−0.109 to −0.00726) |
| Somali             |               | −0.2448 (0.0304)| (−0.3043 to −0.1853)  | −0.2464 (0.03141)| (−0.3079 to −0.1848) |
| Tigray             |               | 0.000          | 0.000                 | 0.000          | 0.000                 |
| **Place of residence** |         |                |                       |                |                       |
| Rural              |               | −0.0157 (0.0175)| (−0.05 (0.0186)      | −0.0169 (0.01827)| (−0.05272 to 0.1891) |
| Urban              |               | 0.000          | 0.000                 | 0.000          | 0.000                 |
| **Sex of household** |          |                |                       |                |                       |
| Female             |               | 0.0158 (0.0152)| (−0.0141 to 0.0456)   | 0.01544 (0.01576)| (−0.01544 to 0.04633) |
| Male               |               | 0.000          | 0.000                 | 0.000          | 0.000                 |
| **Wealth index**   |               |                |                       |                |                       |
| Middle             |               | −0.1207 (0.0221)| (−0.1639 to −0.0775)  | −0.1233 (0.02308)| (−0.1686 to −0.07808) |
| Poorer             |               | −0.1227 (0.0219)| (−0.1657 to −0.0797)  | −0.1259 (0.02294)| (−0.1709 to −0.08097) |
| Poorest            |               | −0.1317 (0.0223)| (−0.1754 to −0.088)   | −0.1349 (0.02332)| (−0.1806 to −0.08921) |
| Richer             |               | −0.1258 (0.0213)| (−0.1676 to −0.0841)  | −0.1276 (0.02229)| (−0.1713 to −0.08387) |
| Richest            |               | 0.000          | 0.000                 | 0.000          | 0.000                 |
| **Contraceptive use** |          |                |                       |                |                       |
| No                 |               | −0.0553 (0.0119)| (−0.0786 to −0.0319)  | −0.05576 (0.0124)| (−0.08007 to −0.03146) |
| Yes                |               | 0.000          | 0.000                 | 0.000          | 0.000                 |
| **Age of mothers at 1st birth** |      |                |                       |                |                       |
| <20                |               | 0.399 (0.2104)| (−0.0135 to 0.8114)   | 0.3974 (0.2113)| (−0.0167 to 0.8115)   |
| 20–34              |               | 0.308 (0.2105)| (−0.1046 to 0.7206)   | 0.3058 (0.2114)| (−0.1085 to 0.7201)   |
| >34                |               | 0.000          | 0.000                 | 0.000          | 0.000                 |
| **Mothers’ marital status** |    |                |                       |                |                       |
| Divorced           |               | 0.0893 (0.0311)| (0.0283 to 0.1503)    | 0.08917 (0.03239)| (0.02567 to 0.1527)   |
| Married            |               | 0.0756 (0.027)| (0.0228 to 0.1285)    | 0.07516 (0.0280)| (0.02027 to 0.1301)   |
| Widowed            |               | 0.000          | 0.000                 | 0.000          | 0.000                 |
| **Household head education level** |      |                |                       |                |                       |
| No education       |               | −0.1226 (0.0241)| (−0.1698 to −0.0753)  | −0.1221 (0.02502)| (−0.1711 to −0.07307) |
| Primary            |               | −0.1018 (0.0246)| (−0.1499 to −0.0537)  | −0.1014 (0.02546)| (−0.1513 to −0.05153) |
| Secondary and above|               | 0.000          | 0.000                 | 0.000          | 0.000                 |

Continued
The birth intervals of over one-fifth of mothers (26.8%) were 1 year. This violates the rule and regulations recommended by the WHO. WHO states come up with at least 2–3 years between successive pregnancies is advisable to reduce the adverse health problems of newborn children and mothers. Short birth intervals increase the risk of several unfavourable perinatal outcomes, including stillbirth, neonatal mortality, low birth weight, preterm delivery and infants tiny for gestational age. This also has a significant detrimental impact on maternal morbidity and death as well. As a result, a birth interval longer than 3 years would be more advantageous which made mothers recover well. Besides, a child would be free from a lack of breast feeding and other care from families due to early followers of a newborn child.

The birth intervals of a mother have slightly a decreasing trend over time. In particular, the birth intervals of mothers who have delivered female children had lower birth intervals than mothers who have delivered male children. This might be because of that often it is perceived to shorten the birth interval to get a male child when women have more female children and have a female last child. This is because of the culture and beliefs of the communities. In Africa and Asia, males are considered to be the leader, head, and pillar of every routine in and out of the house over females. Males are frequently seen as a strength; they will likely support their family in the future and take care of their parents when they age. Thus, commonly they prefer to have male babies as compared with females. In this study, it was also noted that successive birth intervals have their correlation which implies that lower birth intervals in the previous delivery were associated with lower birth intervals in the next delivery and vice versa. The average birth intervals of women decreased from 3.06 to 2.43 years throughout the twelve successive birth intervals sequence. On the other hand, the variability between birth intervals among mothers decreased from 2.01 to 1.31 throughout the entire time. This might be because most mothers are eager to have more children before their fertility age is stopped and to achieve their own desired number of children.

The estimated effects of socioeconomic, demographic, behavioural and biological characteristics on birth interval obtained from GEE and GLMM statistical approaches were closer to each other. However, reports in Zhang et al. that GEE approaches enjoy more advantages over their GLMM-based counterpart for count outcome of interest and not met a normality assumption. This consistency might be because of that in this study adequate number of observations are incorporated. Like the study findings in the wealth index, contraceptive use had a significant effect on birth intervals. In this study, it was perceived that as compared with the birth intervals of mothers from a household with higher economic status, the birth intervals of mothers from a household with lower economic status had lower birth intervals. This was in line with a study based on 2016 EDHS in Ethiopia reported that women belonging to a higher wealth index had a birth interval that is longer than women belonging...
to a lower wealth index. This might be due to a common household with low economic status in Ethiopia considering a higher number of children as a wealth to improve their future life. Mothers who have experience with contraceptive use had higher birth intervals as compared with mothers who do not have experience with contraceptive use and it is consistent with studies conducted in Africa\textsuperscript{2} and Asia.\textsuperscript{7}

In this study, significant effects of religion, region, mothers’ current age, education level and mothers’ current marital status on birth intervals were also noted. Mothers from Muslim religions were less likely to have longer birth intervals as compared with the birth intervals of mothers from protestant and orthodox religions. This is probably because often Muslim mothers have poor practices of using contraceptives to the doctrine of their religion which is in line with a study in Tesfaw and Muluneh.\textsuperscript{30} This is also supported as the birth intervals of mothers from the Harari and Somali regions were shorter than the birth intervals of mothers who are living in Tigray. This is probably because of proportion Muslim followers in Harari (over 95%) and Somali (over 94%) region was higher. This is consistent with the studies\textsuperscript{20,22} that reported that Muslim fertility remains higher than Christian fertility in low-income and middle-income countries with significant Muslim minority populations. Like a study conducted in Uganda,\textsuperscript{18} the findings in this paper revealed that the birth intervals of young women were not significantly different from the birth intervals of old women. This could be because the likelihood of women’s fertility decrease as women get older. It implies the implication that the birth intervals of mothers would be different over time. The birth intervals of illiterate mothers were shorter than the birth intervals of educated mothers which are in line with a study reported in Dehesh et al\textsuperscript{33} that reported that household education level has positive effects on birth intervals of mothers’.

To end, the findings of this study are helpful for policymakers, health planners and executors to design proper future policies to maintain desired birth intervals and manage fertility using approaches such as empowering the awareness about inadequate birth intervals and important determinants obtained in addition to contraceptive use so that maternal and child health improved. Besides, the findings report may use as input for future researchers in related areas.

This study would be more advantageous than previous studies, employing a cross-sectional design, to visualise birth intervals using a longitudinal study design and detecting the most important factors for better policy and decision making as there is a statistically significant link between birth intervals and maternal as well as child health. In contrast, this study has its limitation as all children, mothers and household characteristics are not considered in the study. Therefore we recommended that further studies on this topic include other important covariates that were not included in this study which could have a potential confounding effect.

**CONCLUSION**

The prevalence of mothers who have shorter birth intervals was higher which violates the birth interval recommended by WHO standards. It was also perceived that the intervals between successive births were statistically correlated. In this study, significant effects of religion, contraceptive use, region, mothers’ current age, education level and mothers’ current marital status on birth intervals were also identified. Mothers who have delivered female children had lower birth intervals than mothers who have delivered male children over time. As compared with the birth intervals of mothers from a household with higher economic status, the birth intervals of mothers from a household with lower economic status had lower birth intervals. Mothers from the Muslim religion were less likely to have longer birth intervals as compared with the birth intervals of mothers from protestant and orthodox religions. Finally, the authors would like to recommend that practical awareness is given to improve maternal and child health by having longer birth intervals within successive birth by taking into account the important determinants identified in this and other related findings.

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