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Count Models Analysis of Factors Associated with Under-Five Mortality in Ethiopia

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Abstract

Background. Under-five mortality has continued a key challenge to public health in Ethiopia, and other sub-Saharan Africa countries. The threat of under-five mortality is incessant and more studies are needed to generate new scientific evidence. This study aimed to model the number of under-five deaths a mother has experienced in her lifetime and factors associated with it in Ethiopia. *Method*. A retrospective cross-sectional study based on data obtained from the Ethiopian Demographic and Health Survey (DHS), 2016 was used. The response variable was the total number of under-five children died per mother in her lifetime. Variables such as maternal socioeconomic and demographic characteristics, health, and environmental factors were considered as risk factors of under-five mortality. Hurdle negative binomial (HNB) regression analysis was employed to determine the factors associated with under-five mortality. *Results*. The data showed that 27.2% (95%CI: 0263, 0.282) of women experienced under-five deaths. The study revealed the age of mother at first birth, the age of mother at the time of under-five mortality occurred, number of household members, household access to electricity, region, educational level of the mother, sex of household head, wealth index, mother residing with husband/partner at the time of under-five mortality occurred as factors associated with under-five mortality. Age of mother at first birth 18 to 24 (IRR = .663; 95%CI: 0.587, 0.749), 25 or higher years old (IRR = 0.424; 95%CI: 0.306, 0.588), access to electricity (IRR = 0.758; 95%CI: 0.588, 0.976), primary education level of the mother (IRR = 0.715; 95%CI: 0.584, 0.875) and the richer wealth index (IRR = 0.785; 95%CI: 0.624, 0.988) were associated with reduced incidence of under-five mortality controlling for other variables in the model. Whereas older age of mother 35 to 39 (IRR = 5.252; 95%CI: 2.992, 9.218), 40 to 44 (IRR = 7.429; 95%CI: 4.188, 13.177), 45 to 49 (IRR = 8.697; 95%CI: 4.853, 15.585), being a resident of the Benishangul-gumuz region (IRR = 1.781; 95%CI: 1.303, 2.434), female household head (IRR = 1.256; 95%CI: 1.034, 1.525) were associated with an increased incidence of under-five mortality. *Conclusion*. The findings suggested that early age of mothers' at first birth and old ages of mothers', female household head and being uneducated were found to increase the incidence of the under-five mortality, whereas access to electricity and living with husband was statistically associated with reduced incidence of under-five mortality. The implication of this study is that policymakers and stakeholders should provide health education for mothers not to give birth at an earlier age and improve living standards to achieve sustainable development goals.

Keywords

under-five mortality, count models, over-dispersion, hurdle negative binomial, Ethiopia

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Introduction

Under-five mortality rate (UFMR), the death of a child within the first 5 years of life is important markers of the socioeconomic, health, environmental conditions, and national development indicators of health equity

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and access.[1,2] Under-five mortality is considered a thoughtful measure of the general health of a population, although its exact clarification has been debated. It is an indicator of the health status of the community, mainly the quality of health care services mothers get during pregnancy and after birth. It is also a measure of the socioeconomic and environmental conditions in which the mother lives.[1,3]

Globally, the under-five mortality rate has fallen from 93 deaths per 1000 live births to 41 deaths per 1000 live births, which corresponds to a 52% reduction in the past 25 years in 2016.[1,4] Most of the world's under-five mortality is from developing countries. More than 25% of all under-five deaths worldwide occur in Africa.[5] Although there is a global decline, in the death rates of under-five children in sub-Saharan Africa remains the region with the highest under-five mortality rate.

In sub-Saharan Africa, under-five mortality is still a major public health issue.[6] The most common causes of mortality among under-five children were preterm birth complications, pneumonia, birth asphyxia, diarrhea, malaria, congenital anomalies, and neonatal infections.[7] Removal of these preventable causes is essential to achieve significant improvement in public health and to avoid more than 80% of the total under-five deaths in developing countries through strengthening health systems.[1] It adds a significant premium to the decline of under-five mortality through the health care system by impacting mothers' ability to seek health care for their newborns.

Even though different actions have been taken to reduce under-five mortality, most of the sub-Saharan countries show very high under-five mortality rates. For every 11 infant children in sub-Saharan Africa, 1 child will die before the age of 5.[8] This might be due to the scarce health care centers, poor economic development, poor child feeding practices, a high fertility rate, and poor health systems in the region. In Sub-Saharan Africa, the under-five mortality rate was 77.5 per 1000 live births; this was 15 times her than developed countries in 2018.[9]

Over the last 2 decades, Ethiopia has made significant measure by reducing under-five mortality toward achieving the Millennium Development Goal 4. In the face of many attempts so far done in Ethiopia to improve under-five and maternal mortality rates, this is still a major problem. Evidence from the recent Ethiopian Demographic and Health Survey 2016 (EDHS-2016), shows that under-five mortality rates in Ethiopia are estimated 67 deaths per 1000 live births, ranging from the lowest 39 deaths per 1000 livers in Addis Ababa to highest 125 deaths per 1000 live births in Afar region.[10] This means that 1 in 15 children in Ethiopia, dies before reaching age 5. Additionally, the United Nations (UN) estimated in 2018 that the UFMR in Ethiopia was 55.5 per 1000 live births.[11] Even though there is a significant reduction of under-five mortality by 60% from 2000 to 2016, still under-five mortality in the country is high compared to other regions. Death of a child under the age of 5 is currently a critical public health issue that requires instant attention from policymakers and other decision-makers. Thus, to ensure sustainability in achieving the reduction in under-five mortality toward the sustainable development goals policymakers have set guidelines and address these risk factors with proper intervention.

Ethiopia has made impressive progress in the reduction of child mortality in the past 2 decades[12,13] due to the incessant implementation of a national strategy for child survival to address the high levels of child mortality through the health service extension program and policies. The national strategy for child survival aims to ensure the greatest possible reduction of mortality among the children of the poorest and most marginalized sections of the population, to contribute to the reduction of maternal mortality, and to assure the availability of quality essential health care for women and children in the community, and health facilities. Some strategies include reducing poverty, improving food security, raising levels of maternal education and the status of women in society, and the provision of safe water and sanitation.[14] However, despite the spelled out commitments and programs, under-five, infant and neonatal mortality still remains considerably high in Ethiopia compared to WHO standards.

So far, in various areas of the world,[15-20] and also in Ethiopia,[13,21-24] different studies have been carried out on under-five mortality. Most of these studies focused to identify determinants of under-five mortality/survival of the recently born children, and also used binary logistic regression or Cox proportional regression models. Moreover, different approaches are commonly used to model the number of under-five deaths a woman has experienced in her lifetime. These models might be more recommended to measure the incidence of under-five mortality a woman has experienced in her lifetime and associated factors. There is a need for data on the lifetime experience of under-five mortality and more research is therefore needed to update the formulation of policies and execution of programs for the right health intervention. Furthermore, to the best of our knowledge, none of these researches in Ethiopia used over-dispersed count data models that can handle excess zeroes and heteroskedasticity. Therefore, this study aims to identify the major factors determining the number of under-five deaths that a woman has experienced throughout her lifetime in Ethiopia via the appropriate count regression models.

Methods

Study setting, data, and study population

This study was based on a retrospective cross-sectional analysis of data from the 2016 Ethiopian Demographic and Health Survey.[10] The Central Statistical Agency (CSA) in collaboration with the Ministry of Health (MOH) and the Ethiopian Public Health Institute piloted the survey from January 18 to June 27, 2016, while the United States Agency for International Development (USAID) was sponsored the survey. The data was obtained from the DHS MEASURE Program[25] which contains information on a range of socioeconomic and demographic factors of the population nationwide.

The Ethiopian DHS 2016 implemented a 2-stage sample design to select respondents within the 9 regions and 2 administrative cities of a country. In the first stage, 645 enumeration areas were selected with probability proportional to size. The second stage comprised the selection of 28 households per cluster of an equal chance of being counted in the systematic selection of the newly made household list. All women of 15 to 49 years old, who were either permanent inhabitants or visitors who lived at least 1 night in the family prior to the survey, were eligible for the interview. Full birth histories were collected comprising month and year of each biological child's birth and death. Retrospective data was collected about children that died in the past 5 years based on information on all births to a woman within 5 years prior to the survey. Data was gathered by conducting face-to-face interviews for women who met the eligibility criteria.

Overall of 15 683 eligible women were interviewed. However, the models fitted to the data was based on 8528 respondents with complete information on children born 5 years, preceding the survey.

Study variables

The outcome variable in this study was defined to be the total number of children who died under the age of 5 per woman in her lifetime measured as count 0, 1, 2, ... The predictor variables that are included in this study were age of mother at first birth (11-17, 18-24, 25 or higher); age of mother at the time of under-five mortality occurred (24 or less, 25-29, 30-34, 35-39, 40-44, 45-49); number of household members (4 or less, 5-7, 8 or more); husband's working status (not working, agricultural sector, professional, skilled/unskilled manual, others); source of drinking water (piped water, tube-well, others); type of toilet facility (no facility/bush/field, with facility); access to media (no access, with access); household access to electricity (no, yes); number of under 5 children in the household (no children, 1-2, 3 or more); administrative region (Tigray Afar Amhara, Oromia, Somali, Benishangul, Southern Nations Nationalities and People of Ethiopia Region (SNNPR), Gambela, Harari, Addis Ababa, Dire Dawa); type of place of residence (urban, rural); educational level of mother (no education, primary, secondary, higher); religion of mother (Orthodox, Catholic, Protestant, Muslim, Traditional, others); sex of household head (male, female); household wealth index (poorest, poorer, middle, richer, richest); mother residing with husband/partner (living with her husband, staying elsewhere); mother working status (working, not working); and husband/partner's education level (no education, primary, secondary, higher). Data was analyzed with STATA 13.[26]

Statistical analysis

Under-five mortality data experience excess zeros characterized by over-dispersion and heteroscedasticity. The most popular distribution for modeling such data was the zero-inflated model and hurdle models. The over-dispersion has been explained as heterogeneity that has not been accounted for unobserved (ie, the population consists of several sub-populations, in this case of Poisson type, but the sub-population membership is not observed in the sample). This excess variation may occur incorrect inference about parameter estimates, standard errors, tests, and confidence intervals. The Negative binomial model addresses the issue of over-dispersion by including a dispersion parameter to accommodate the unobserved heterogeneity in the count data.[27] However, it cannot address the over-dispersion caused by an excessive number of zeros, in such case zero-inflated and Hurdle models are appropriate. Zero-inflated models[28] mixes a count component and a point mass at zero, allowing for over-dispersion.[29]

Hurdle models[30] combine a left-truncated count component with a right-censored hurdle component. In the hurdle formulations, a binomial probability model governs the binary outcome, whether a count variate has a zero or a positive realization (number of under-five deaths). If the realization is positive the "hurdle" is crossed, and the conditional distribution of the positives is governed by a truncated-at-zero count data model, such as a truncated Poisson or truncated negative binomial distribution.[31]

There are situations where a major source of over-dispersion is a relatively large number of zero counts, and the resulting over-dispersion cannot be modeled accurately with the negative binomial model. In such cases, one can use the zero-inflated Poisson (ZIP) or zero-inflated negative binomial (ZINB) model to fit the data characterized by over-dispersion and excess zeros.[28] Such models assume that the data are a mixture of 2 separate data generation processes: 1 generates only zeros, and the other is either a Poisson or negative binomial data-generating process. If there are sources of over-dispersion that cannot be attributed to the excess zeros, failure to account for them constitutes model misspecification, which results in biased standard errors.

In ZIP models, the underlying Poisson distribution for the first subpopulation is assumed to have a variance that is equal to the distribution's mean. If this is an invalid assumption, the data exhibit over-dispersion (or under dispersion). The probability distribution of a zero-inflated Poisson random variable is given by:

$$P(Y_i = y_i) = \begin{cases} \omega_i + (1-\omega_i)e^{-\mu}, y_i = 0 \\ (1-\omega_i)\dfrac{e^{-\mu_i}\mu_i^{y_i}}{y_i!} y_i = 1,2,\ldots 0 \le \omega_i \le 1 \end{cases} \quad (1)$$

where, $y_i = 1,2,\ldots$ represent the number of under-five deaths per ith mother in a given time or exposure periods with the rate $\mu \ge 0$ for Poisson distribution.

The mean and variance of Zero-inflated Poisson (ZIP) distribution is $E(Y_i) = (1-\omega_i)\mu_i$, and $var(Y_i) = E(Y_i)(1+\omega_i\mu_i)$. A useful diagnostic tool that can aid in detecting over-dispersion is the Pearson chi square statistic.

Furthermore, the theory suggests that the excess zeros are generated by a separate process from the count values and that the excess zeros can be modeled independently. In such cases, zero-inflated negative binomial regression is recommended for modeling count variables with excessive zeros, and usually for over-dispersed. The probability distribution of a zero-inflated negative binomial is given by:

$$P(Y_i = y_i) = \begin{cases} \omega_i + (1-\omega_i)(1+\delta\mu_i)^{-1/\delta}, y_i = 0 \\ (1-\omega_i)\dfrac{\Gamma(y_i + \frac{1}{\delta})}{y_i!\Gamma(\frac{1}{\delta})}(1+\delta\mu_i)^{-1/\delta} \\ (1+\dfrac{1}{\delta\mu_i})^{-y_i} \end{cases}, y_i > 0 \quad (2)$$

where $\delta > 0$ is a dispersion parameter and is assumed not to depend on covariates. The mean and variance of the ZINB model are $E(Y_i) = (1-\omega_i)\mu_i$ and $var(Y_i) = (1-\omega_i)(1+\omega_i\mu_i+\delta\mu_i)\mu_i$

The method of Fisher scoring is used to obtain the parameter estimates of ZINB regression models since the zero-inflated negative binomial (ZINB) distribution is not a standard generalized linear model.

Hurdle count models are 2-component models with a truncated count component for positive counts, and a hurdle component that models the zero counts. The count model is typically a truncated Poisson or negative binomial regression (with log link). The probability mass function of the hurdle model given by:

$$p\begin{pmatrix} y=y_i / \\ x_i, z_i, \beta, \gamma \end{pmatrix} = \begin{cases} f_{zero}(0; z_i; \gamma) & if\ y_i = 0 \\ (1 - f_{zero}(0; z_i; \gamma)) \\ (\dfrac{f_{count}}{(1-f_{count}}(y_i; x_i; \beta)) & \text{if } y_i > 0 \\ (0; x_i; B) \end{cases} \quad (3)$$

where y_i is the number under-five death for the i^{th} mother $i = 1, \ldots, n$), z_i is a vector of length j denoting the number of predictor variables in zero part, x_i represents a vector of length k denoting the number of predictor variables in the hurdle part, γ is a vector of coefficients belonging to z, and β denotes a vector of coefficients related to x. $f\ zero$ is a probability density function at least on {0, 1} (binary) or {0, 1, 2, . . .} (count), and $f\ count$ is a probability density function on {0, 1, 2, . . .}. The regression coefficients are estimated by maximum likelihood. The f_{zero} part (where $y_i = 0$) is typically modeled with a binary logit (logistic regression) model, where all counts greater than 0 are given a value of 1.[31]

The likelihood-ratio test is used to test the null hypothesis of no over-dispersion (ie, the Poisson model is preferred) against the alternative hypothesis the over-dispersion parameter is different from zero (ie, the data would be better fitted by the negative binomial regression). The Voong test statistics are needed to test the appropriateness of zero-inflated models against the standard count models comparing the predicted probabilities of 2 models.[32] Furthermore, Akaike information criterion (AIC) and Bayesian information criterion (BIC) were used to compare various candidate models, and the model with the smallest AIC and BIC value is considered as a better fit.[33] The Deviance and Pearson Chi-square statistics were used for testing overall model goodness of fit[31]

Ethical approval and informed consent. This study is a secondary data analysis of the Ethiopian Demographic Health Survey, 2016. The data is openly accessible, with approval required from MEASURE DHS/ICF International, and authorization was granted for this use.

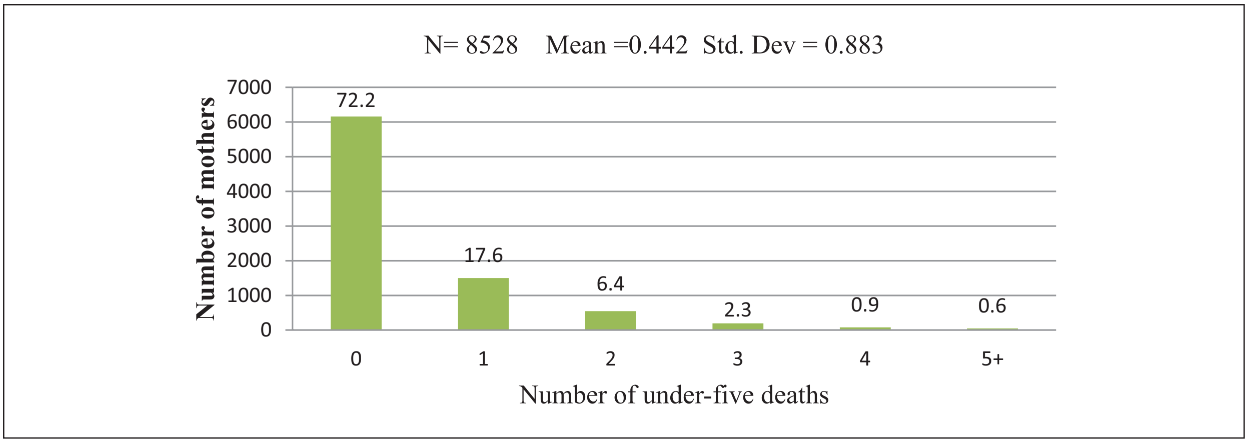

Figure 1. Distribution of number of deaths of children under-five age a woman has experienced in her life time in Ethiopia, EDHS 2016.

Results

Data exploratory

The study revealed that the mean number of under-five deaths a mother had experienced in her lifetime was 0.442 95%CI (0.423, 0.460) with a variance of 0.779. Figure 1 showed that the variance of the number of children who died under-five ages was greater than the mean, implying there is a possibility of over-dispersion. Also, the distribution of the number of under-five deaths is skewed to the right. As shown in Figure 1 there is a massive count of zeros, that is, the bar charts are highly picked at the zero values. However, larger observations (ie, experiencing many under-five deaths) are less frequently observed. This implies count data models that take into account excess zero, such as zero-inflated models, and hurdle models might deliver a better fit (Figure 1).

The expected number of under-five mortality was highest (mean = 0.58) among mother 11 to 17 years old at first birth and lowest (mean = 0.24) among mother aged 25 or higher years old at first birth, suggesting that the expected number of under-five mortality is negatively correlated with age of mother at first birth. Considering the current age of the mother, the highest mean number of experiencing under-five mortality (mean = 1.055) was reported among 45 to 49 years of old mothers while the smallest (mean = 0.12) was reported among mothers 24 or lower years old. Similarly, more than 5 members of household size had associated with the highest mean number of under-five mortality (mean = 0.50); on the other hand, the lower expected number of experiencing under-five mortality (mean = 0.31) was reported among households with 4 or lower members.

It is also shown that the highest expected number of experiencing under-five deaths was reported among families who use tube-well drinking water sources (mean = 0.52) and have no access to toilet facilities (mean = 0.523). The expected number of under-five mortality was also higher among households who had no access to media (mean = 0.47) than those who had access to media (mean = 0.37). Furthermore, the average of the number of under-five mortality was higher among households that had no access to electricity (mean = 0.52). As region of residence was concerned Table 1 showed that the lowest mean number of experiencing under-five mortality was reported in Addis Ababa (mean = 0.08), whereas the highest was reported in Afar (mean = 0.628), followed by Benshangul-Gumuz (mean = 0.572) and Somali (mean = 0.525). On the other hand, regarding the place of residence, a large mean number of under-five mortality was reported in rural areas (mean = 0.51).

Uneducated mothers had the highest expected number of experiencing under-five mortality (mean = 0.587) than educated mothers. The average number of under-five mortality also varies by religion of the mother, with Orthodox (mean = 0.35), protestant (mean = 0.39), Catholic (mean = 0.52), Muslim (mean = 0.53) and traditional (mean = 0.51) and others (mean = 0.48). On the other hand, the expected number of under-five mortality was highest (mean = 0.57) among the poorest wealth index and lowest (mean = 0.21) among the richest quintile suggesting that the wealth index was negatively correlated with the expected number of experiencing under-five mortality. The expected number of experiencing under-five mortality was nearly equal among respondents currently not working. Likewise, respondents whose husband were illiterate has reported a higher average number of under-five mortality (mean = 0.591; Table 1).

Test of over-dispersion, goodness-of-fit test, and model comparison

The formal test of over-dispersion (δ), testing the null hypothesis of there is no over-dispersion in the dataset was performed using the likelihood ratio test. It was found that the over-dispersion parameter is significant (likelihood ratio test statistic = 300.12, P-value < 0.001), implying there is over-dispersion in the data set which favors the NB regression model. Since the result of Figure 1 shows excess zeros in the data set this might be due to the presence of excess zeros or both.

Six different models, namely; Poisson, negative binomial, zero-inflated Poisson, zero-inflated negative binomial model, hurdle Poisson, and hurdle negative binomial model computed and, the HNB model was selected as the AIC and BIC were the smallest as shown in Table 2. Moreover, the log-likelihood test of the Hurdle negative binomial regression model is better fitted than others. Likewise, the calculated value of the Vuong statistic (V = 9.31, P-values < 0.001) and (V = 5.84, P-values < 0.001) for comparing ZIP versus Poison and ZINB versus NB models was significant, indicating that the ZIP is preferred to Poison and ZINB model is preferred to NB regression model. Finally, the hurdle negative binomial regression model was the best fit for the data, based on their corresponding log-likelihood, AIC, and BIC. Hence, the HNB model with a combination of covariates was used (Table 2).

Factors associated with the number of under-five mortality interpretation of HNB model

Table 3 depicted the result of a hurdle negative binomial model of parameter estimates, incidence rate ratio (IRR), standard error of the estimates, P-values, and 95% CI for IRR. The model has 2 parts. The first part is from the equation predicting non-zero counts of numbers of under-five deaths (truncated negative binomial with log link) interpreted similarly to the standard negative binomial model. The second part of the model predicts the zero hurdle model (binomial with logit link) zero deaths versus not zero deaths. After adjusting other covariates age of mother at first birth, the current age of mother, household size, household access to electricity, region, educational level of the mother, sex of household head, wealth index, and currently residing with husband/partner were found statistically significant predictors of under-five mortality in the non-zero count part.

According to Table 3, mothers, age at birth 18 to 24 years were associated with a 33.67% (IRR = 0.663; 95%CI: 0.587, 0.749) decreased incidence of experiencing under-five deaths, whereas those mothers aged 25 years or higher, had a 58.62% (IRR = 0.423; 95%CI: 0.306, 0.588) decreased incidence of experiencing under-five mortality as compared mothers aged 11 to 17 years at first birth. The age of a mother was found positively statistically associated high incidence of experiencing under-five mortality. Mothers with age of 45 to 49 years at the time of under-five deaths were about 9 times (IRR = 8.697; 95%CI: 4.853, 15.585), 40 to 44 years 7.429 time (IRR = 7.429; 95%CI: 4.188, 13.177), 35 to 39 years, 5.2516 times (IRR = 5.252; 95%CI: 2.992, 9.218), 30 to 34 years 3.826 times (IRR = 3.826; 95%CI: 2.198, 6.658) and 25 to 29 years 2.1984 times (IRR = 2.198; 95%CI: 1.515, 4.394) more likely at the risk of experiencing under-five mortality, respectively, compared to mothers whose age at the time of under-five mortality occurred is 24 or less.

The estimated incidence of experiencing under-five mortality by a mother in her lifetime was statistically negatively associated with household access to electricity. The results in Table 3 showed that household access to electricity has a significant impact on the incidence of under-five deaths per woman in zero truncated groups. The incidence of under-five deaths of a mother belongs to households who had access to electricity was 25% (IRR = 0.758; 95%CI: 0.588, 0.978) time lower than that of households who had no electricity. Concerning the regional distribution of under-five mortality a mother has experienced in her lifetime, a mother from the Benishangul-gumuz region has 78% (IRR = 1.781; 95%CI: 1.303, 2.434) higher incidence of experiencing under-five mortality than the Tigray region holding all others variables constant.

The HNB model also revealed that the education level of the mother is negatively statistically associated with a number of under-five mortality. The primary education level of the mother was associated with a 29% decreased incidence of under-five mortality than a mother with no education (IRR = 0.715; 95%CI: 0.584, 0.875) controlling for other variables in the model. On the other hand, the incidence of children who died under-five years of age per mother of female household head was 1.25 (IRR = 1.256; 95%CI: 1.034, 1.525) times more likely compared to that of the male household head. Household wealth index was another factor statistically significantly associated with the number of under-five deaths. The richer wealth index was associated with 22% (IRR = 0.785; 95%CI: 0.624, 0.988) lower incidence of under-five deaths than the poorest wealth index. Furthermore, the incidence of experiencing under-five

Table 1. Descriptive Statistics of Under-Five Mortality a Woman Has Experienced in Her Lifetime by Socioeconomic and Demographic Characteristic of Mother in Ethiopia, EDHS 2016.

Variables	Categories	n	%	Mean	Std. deviation
Age of mother at first birth	11-17	3392	39.8	0.585	1.031
	18-24	4462	52.3	0.363	0.776
	25 or higher	674	7.9	0.240	0.594
Current age of mother	24 or less	1657	19.4	0.121	0.365
	25-29	2012	23.6	0.252	0.591
	30-34	1730	20.3	0.392	0.749
	35-39	1494	17.5	0.589	0.944
	40-44	973	11.4	0.821	1.245
	45-49	662	7.8	1.056	1.376
Number of household members	4 or less	2812	33.0	0.317	0.789
	5-7	4098	48.1	0.500	0.925
	8 and more	1618	19.0	0.509	0.905
Husband's working status	Not working	917	10.8	0.489	1.007
	Agricultural sector	4461	52.3	0.529	0939
	Professional	1358	15.9	0.278	0.705
	Skilled/unskilled manual	1046	12.3	0.298	0.739
	Others	746	8.7	0.358	0.775
Source of drinking water	Piped water	2943	34.5	0.301	0731
	Tube-well	2368	27.8	0.524	0.948
	Others	3217	37.7	0.509	o.944
Type of toilet facility	No facility/bush/field	3272	38.1	0.523	0.945
	With facility	5256	61.9	0.392	0.836
Access to media	No access	5933	69.6	0.474	0.907
	Access	2595	30.4	0.367	0.821
House hold access to electricity	No	6076	71.2	0.521	0.952
	Yes	2452	28.8	0.244	0.641
Number of under-five children in the household	No children	1822	21.4	0.666	1.129
	1-2	5895	69.1	0.381	0.795
	3 and more	811	9.5	0.375	0.776
Region	Tigray	821	9.6	0.357	0.787
	Afar	707	8.3	0.628	1.067
	Amhara	962	11.3	0.477	0.866
	Oromia	1189	13.9	0.432	0.883
	Somali	872	10.2	0.525	0.935
	Benishangul-gumiz	722	8.5	0.572	1.110
	SNNPR*	1127	13.2	0.497	0.907
	Gambela	614	7.2	0.353	0.691
	Harari	500	5.9	0.322	0.695
	Addis Ababa	528	6.2	0.089	0.345
	Dire Dawa	486	5.7	0.412	0.896
Type of place of residence	Urban	1992	23.4	0.210	0.618
	Rural	6536	76.6	0.512	0.938
Educational level of mother	No education	5267	61.8	0.587	1.012
	Primary	2214	26.0	0.244	0.597
	Secondary	666	7.8	0.165	0.459
	Higher	381	4.5	0.066	0.287
Religion	Orthodox	2970	34.8	0.350	0.759
	Catholic	51	0.6	0.529	0.809
	Protestant	1616	18.9	0.392	0.825

(continued)

Table 1. (continued)

Variables	Categories	n	%	Mean	Std. deviation
	Muslim	3771	44.2	0.532	0.983
	Traditional	68	0.8	0.515	1.058
	Others	52	0.6	0.481	0.779
Sex of household head	Male	7029	82.4	0.452	0.888
	Female	1499	17.6	0.394	0.860
Household wealth index	Poorest	2578	30.2	0.576	1.002
	Poorer	1348	15.8	0.507	0.939
	Middle	1216	14.3	0.467	0.878
	Richer	1176	13.8	0.467	0.889
	Richest	2210	25.9	0.217	0.617
At the time of under-five death mother	Mother live with husband	7549	88.5	0.452	0.895
	Staying elsewhere	979	11.5	0.359	0.783
Mother currently working	No	5813	68.2	0.454	0.897
	Yes	2715	31.8	0.416	0.8525
Husband/partner's education level	No education	4042	47.4	0.591	1.029
	Primary	2727	32.0	0.394	0.799
	Secondary	987	11.6	0.170	0.465
	Higher	772	9.1	0.172	0.502

*Southern Nations Nationalities and People of Ethiopia Region.

Table 2. Model Selection and Comparison of Number of Under-Five Mortality in Ethiopia, EDHS 2016.

	Models					
Selection criteria	Poisson	NB	ZIP	ZINB	HP	HNB
Log likelihood	−6754.35	−6604.29	−6552.95	−6549.1	−6560.4	−6535.8
AIC	13618.71	13320.6	13319.9	13295.7	13340.8	13293.7
BIC	14005.28	13715.2	14101.03	14075.9	14045.6	13030.7

mortality was found 27% (IRR = 0.738; 95%CI 0.574, 0.949) lower among mothers living with the husband than that of living elsewhere (Table 3).

Interpretation for Covariates of Zero Counts (Binomial with Logit Link) Model

The second parts of Table 3 provide estimated odds ratio (AOR) and 95%CI for the factor change in the odds of being in zero counts group (binomial with logit link) model (no under-five death) compared to the non-zero count group (at least 1 under-five deaths). Age of mother at first birth, current age of mother, household size, occupation of husband, sources of drinking water, geographical region, mother's education level, religion of the mother, household wealth index, and husband education level had significantly associated with the probability of being in zero counts group.

The age of the mother at first birth has a significant impact on the probability of being in the always zero groups. The odds of being in the always zero groups decreased by 42.% (AOR = 0.587; 95%CI: 0.526, 0.656) and 71% (AOR = 0.291; 95%CI: 0.229, 0.370) for a mother whose age at first birth was 18 to 24 and 25 or more years, respectively, as compared to those aged 11 to 17 years at first birth. With regard to the current age of mother the odds of being in the always zero group was 2.39 (AOR = 2.395; 95%CI: 1.911, 3.002), 4.28 (AOR = 4.281; 95%CI: 3.302, 5.548), 7.47 (AOR = 7.479; 95%CI: 5.639, 9.919), 9.96 (AOR = 9.964; 95%CI: 7.295, 13.609) and 15.13 (AOR = 15.131; 95%CI: 10.717, 21.362) times more likely for the mother aged 25 to 29, 30 to 34, 35 to 39, 40 to 44, and 45 to 49 years, respectively, compared to 24 or lower aged mother.

On the other hand, the odds of being in the zero counts group was decreased by 25% (AOR = 0.750; 95%CI: 0.649, 0.867) and 47% (AOR = 0.532; 95%CI: 0.439, 0.646) among mothers' with the family size 5 to 7 and at least 8 members of households respectively compared to a household size of 4 or less, respectively, controlling other

Table 3. Factors Associated With Number of Under-Five Deaths, Hurdle Negative Binomial Model, in Ethiopia, EDHS 2016.

	Count model coefficients (truncated negative binomial with log link)				Zero hurdle model (binomial with logit link)			
Variables	IRR	Std. Err.	95% CI for IRR	*P*-values	AOR	Std. Err.	95% CI for AOR	*P*-values
Age at birth								
18-24	0.663	0.041	0.587, 0.749	<.001	0.587	0.033	0.526, 0.656	<.001
25 and more	0.424	0.071	0.306, 0.588	<. 001	0.291	0.036	0.229, 0.370	<.001
11-17 (ref)								
Maternal age								
25-29	2.580	.701	1.515, 4.394	<.001	2.395	0.276	1.911, 3.002	<.001
30-34	3.826	1.082	2.198, 6.658	<.001	4.281	0.567	3.302, 5.548	<.001
35-39	5.252	1.508	2.992, 9.218	<.001	7.479	1.077	5.639, 9.919	<.001
40-44	7.429	2.172	4.188, 13.177	<.001	9.964	1.585	7.295, 13.601	<.001
45-49	8.697	2.588	4.853, 15.585	<.001	15.131	2.663	10.717, 21.362	<.001
24 or less (ref)								
Household members								
5-7	0.829	0.067	0.708, 0.972	.021	0.750	0.055	0.649, 0.867	<.001
8+	0.676	0.072	0.548, 0.833	<.001	0.532	0.053	0.438, 0.646	<.001
4 or less (ref)								
Husband occupation								
Agricultural	0.966	0.091	0.803, 1.162	.715	1.45	0.135	1.207, 1.739	<.0001
Professional	1.022	0.133	0.792, 1.319	.868	1.272	0.151	1.007, 1.606	.043
Skilled/unskilled manual	1.049	0.145	0.801, 1.377	.725	1.334	0.166	1.045, 1.704	.021
Others	0.929	0.133	0.702, 1.232	.613	1.485	0.191	1.155, 1.911	.002
Not working (ref)								
Source of drinking water								
Tube-well	1.952	0.088	0.795, 1.140	.593	1.233	0.104	1.046, 1.454	.013
Others	1.037	0.088	0.877, 1.2252	.671	1.134	0.089	0.973, 1.321	.109
Piped water (ref)								
Toilet facility								
With facility	0.951	0.076	0.813, 1.112	.526	0.978	0.072	0.847, 1.130	.765
No facility (ref)								
Media access								
With access	1.079	0.079	0.935, 1.246	.297	0.927	0.061	0.814, 1.056	.253
No access (ref)								
Electricity								
Yes	0.758	0.098	0.588, 0.978	.033	0.964	0.106	0.777, 1.195	.735
No (ref)								
Children less than 5								
1-2	1.041	0.077	0.901, 1.203	.586	0.958	0.071	0.827, 1.108	.562
3+	1.014	0.142	0.771, 1.333	.923	0.965	0.117	0.760, 1.225	.770
No child (ref)								
Region								
Afar	1.272	0.215	0.912, 1.773	.156	1.685	0.260	1.245, 2.2809	.001
Amhara	0.938	0.133	0.711, 1.237	.649	1.138	0.139	0.896, 1.4459	.289
Oromia	1.058	0.166	0.779, 1.438	.717	1.245	0.164	0.961, 1.6119	.097
Somali	1.122	0.194	0.799, 1.576	.506	1.552	0.233	1.157, 2.083	.003
Benishangul-gumuz	1.781	0.284	1.303, 2.434	<.001	1.165	0.165	0.882, 1.536	.282
SNNPR	1.227	0.195	0.898, 1.676	.199	1.612	0.226	1.225, 2.123	.001
Gambela	0.924	0.184	0.625, 1.366	.692	1.540	0.246	1.126, 2.107	.007
Harari	1.167	0.247	0.770, 1.767	.467	1.175	0.199	0.842, 1.640	.343
Addis Ababa	0.680	0.2736	0.309, 1.496	.338	0.625	0.134	0.410, 0.952	.028
Dire Dawa	1.297	0.253	0.885, 1.900	.183	1.393	0.234	1.003, 1.935	.048

(continued)

Table 3. (continued)

Variables	Count model coefficients (truncated negative binomial with log link)				Zero hurdle model (binomial with logit link)			
	IRR	Std. Err.	95% CI for IRR	*P*-values	AOR	Std. Err.	95% CI for AOR	*P*-values
Tigray (ref)								
Residence								
Rural	0.929	0.135	0.699, 1.234	.609	1.278	0.162	0.998, 1.638	.052
Urban (ref)								
Mother education								
Primary	0.715	0.074	0.584, 0.875	.001	0.786	0.059	0.678, 0.911	.001
Secondary	0.714	0.191	0.423, 1.207	.209	1.019	0.153	0.760, 1.368	.897
Higher	0.865	0.464	0.302, 2.477	.787	0.402	0.106	0.239, 0.672	.001
No education (ref)								
Religion								
Catholic	1.329	0.520	0.617, 2.863	.467	2.328	0.768	1.219, 4.444	.010
Protestant	1.162	0.141	0.916, 1.473	.215	0.959	0.100	0.782, 1.178	.695
Muslin	1.174	0.118	0.964, 1.431	.110	1.459	0.128	1.229, 1.733	<.001
Traditional	1.108	0.330	0.617, 1.987	.732	0.918	0.274	0.511, 1.648	.774
Other	0.999	0.409	0.447, 2.232	.998	1.745	0.572	0.918, 3.317	.089
Orthodox (ref)								
Household head sex								
Female	1.255	0.125	1.034, 1.525	0.022	0.754	0.074	0.623, 0.915	.004
Male (ref)								
Wealth index								
Poorer	0.807	0.076	0.672, 0.970	.023	0.998	0.088	0.839, 1.188	.989
Middle	0.906	0.095	0.738, 1.112	.346	0.819	0.082	0.674, 0.997	.046
Richer	0.785	0.092	0.624, 0.988	.039	0.865	0.095	0.698, 1.071	.183
Richest	0.873	0.151	0.622, 1.226	.434	0.668	0.103	0.493, 0.905	.009
Poorest (ref)								
At the time of under-five death mother residing with								
Staying elsewhere	0.738	0.095	0.574, 0.949	.018	1.062	0.125	0.843, 1.338	.609
Living with husband (ref)								
Mother work status								
Working	0.882	0.059	0.773, 1.007	.063	1.058	0.065	0.938, 1.193	.359
Not working (ref)								
Husband education								
Primary	0.935	0.071	0.806, 1.084	.370	1.065	0.071	0.935, 1.215	.343
Secondary	0.699	0.137	0.476, 1.027	.068	0.739	0.091	0.582, 0.942	.014
Higher	0.772	0.169	0.503, 1.186	.238	0.934	0.142	.693, 1.259	.655
No education (ref)								
Constant	0.231	0.078	0.119, 0.448	<.001	0.074	0.017	0.05, 0.115	<.001
/lnalpha	−1.554	0.299		−2.141				
Alpha	0.211	0.063		.1175				

variables in the model. With regard to husband/partner's occupation, the odds of being in zero counts group was increased by 45% (AOR = 1.449; 95%CI: 1.207, 1.739), 27% (AOR = 1.272; 95%CI: 1.007, 1.606), and 33% (AOR = 1.334; 95%CI: 1.045, 1.704) among mothers whose husband engaged in agricultural, professional, and skilled/unskilled manual, respectively, as compared to those whose husbands not working. Similarly, the source of drinking water has a significant impact on the probability of being in always zero groups. The odds of being in the always zero groups were 1.23 times (AOR = 1.233; 95%CI: 1.046, 1.454) more likely for tube well source of drinking water compared to a piped source of drinking water holding all other variables in the model constant.

Concerning the regional difference the regions Afar, Somali, SNNPR, Gambela, and Dire Dawa had a lower odds of being in the always zero groups compared to the Tigray region (P-values <0.05) As education level was concerned, mothers with primary education level had 0.78 (AOR = 0.786; 95%CI: 0.678, 0.911) and mothers with higher education level had 0.40 (AOR = 0.402; 95%CI: 0.239, 0.672) times decreased odds of being in the always zero groups, respectively compared to mothers with no education at all, holding all others variables in the model constant. Likewise, the odds of being in the zero count group was increased by a factor of 0.739 (AOR = 0.739; 95%CI: 0.582, 0.942) for a mother whose husband has attained at least secondary education compared to non-educated. In contrast, as the religion of the mother was concerned, the odds of being in the always zero groups increased by a factor of 2.32 (AOR = 2.328; 95%CI: 1.219, 4.444) and 1.4597 (AOR = 1.459; 95% CI: 1.229, 1.733) for Catholic and Muslim mothers compared to Orthodox holding all other variables in the model constant. Whereas, the odds of being in the always zero groups decreased by a factor of 0.75 (AOR = 0.755; 95%CI: 0.623, 0.915) for the female household head. In addition, as the household wealth index was concerned the odds of being in the always zero groups decreased by a factor of 0.81 (AOR = 0.819; 95%CI: 0.674, 0.996) and 0.66 (AOR = 0.668; 95%CI: 0.493, 0.905) for middle and richest wealth index, respectively compared to the poorest wealth index.

Discussion

In this study, 8528 mothers who gave at least 1 birth in a lifetime in Ethiopia were assessed, of which, 2368 (27.8%) were experienced at least 1 under-five mortality in a lifetime, and overall the average number of under-five mortality per mother was 0.442 ± 0.009. The HNB model had the smallest AIC and BIC compared to that of Poison, NB, ZIP, ZINB, and HP count models. It was found the HNB model was well fitted to the data than other count models. This is because of the presence of excess zeros of under-five mortality and zero truncated discrete, hurdle distribution is mostly used in the literature as the data characterized by excess zeros and heteroscedasticity[20,28,34] and the Newton-Raphson procedure is used to maximize the best-unbiased estimator for the model parameters.[35] Thus, the under-five mortality in Ethiopia were analyzed using the HNB model. This study identified a number of factors associated with the number of under-five mortality in Ethiopia.

Early age at first birth (11-17 years) was associated with a high likelihood of experiencing under-five mortality. Several other studies have similarly shown those mothers who gave first birth at an early age tend to have under-five mortality.[36,37] This means that women delivered at an early age were experiencing large under-five mortality in their lifetime than those who gave birth at the age of at least 18 years. This might be related to higher tendencies toward poor pregnancy outcomes, and preterm birth which may mediate neonatal mortality. Furthermore, the older current age of the mother also associated with experienced a higher number of under-five mortality than that of the younger mothers. The result is in line with the previous findings in Ethiopia,[37] Pakistan,[38] and India.[39]

Consistent with the findings of Aheto,[19] Khan,[41] and Ayele et al,[13] the education level of mothers was associated with the decreased incidence of under-five deaths compared to the mothers with no education. The female household head was another variable significantly associated with a higher incidence of experiencing under-five mortality. This finding is congruent with the results of previous studies.[40-42] Furthermore, the poor household wealth index was associated with a higher incidence of experiencing under-five mortality. The possible response might be due to poor nutrition difficulty to access health services.[19,23,43] The result is similar to the finding of studies conducted in Ethiopia,[23,24] Nigeria,[44,45] and sub-Saharan Africa.[46] Unlike the finding of Bhutan[47] sources of access to media and availability of sanitary services was not a statistically significant predictor of a number of under-five mortality. This disparity might be due to the sample size difference, model difference, besides the nature of the study participants. The results of this study revealed that access to electricity services was a significant factor in the number of under-five mortality in Ethiopia. These results showed that access to electricity was associated with a lower risk of experiencing under-five mortality. This finding was similar to a study in Bhutan.[47] The results of this study suggested that the risk of experiencing under-five mortality was also varying between geographical regions. Mothers from the Benishangul-gumuz region had a higher risk of experiencing under-five mortality compared to the Tigray region. This was consistent with the study done by Ayele et al[37] in Ethiopia and studies conducted in Bhutan,[47] Mozambique,[48] Ghana,[19] and Nigeria[49] which regional variation in under-five mortality

Conclusion

This study aimed to model over-dispersed count data characterized by excess zeroes and heteroskedasticity with application investigating the major factors associated with under-five mortality in Ethiopia. About 27.2% of women experienced under-five deaths, with mean number of under-five deaths experienced in lifetime 0.442. The hurdle models and zero-inflated models were compared based on various methods and it was found the hurdle negative binomial model better fit under-five mortality data.

The hurdle negative binomial regression analysis revealed that being earlier age at first birth (11-17 years), the older age of mother, female household head, and the poor wealth index were found as factors that positively related to the risk of experiencing a higher number of under-five mortality. On the other hand, access to electricity, at least primary education level of the mother, was found factors that inversely correlated with the number of under-five mortality. However, variables such as place of residence, sanitation service (source of drinking water and toilet facility), husband/partner education, media access, and the number of under-five children in the household were found insignificant. Giving birth at an earlier age in the study setting highly associated with an increased number of under-five deaths a mother experienced in her lifetime, this might be due to high early marriage in the community. Further, a large family size has positively increased the chance of experiencing a large number of under-five deaths in a lifetime. Thus, awareness creation should be given to the community problem of early marriage and early child bearing. Improving mothers' education is a vital input that should be included in all the health policies aiming to reduce under-five deaths in Ethiopia. Moreover, women in Benishangul-gumuz region and in low economic status should be given special emphasis.

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Authors' Contributions

MAA conceived the original idea of the study, design the study, analyzed the data, and drafted the manuscript. BTW involved with the conception of the study, statistical analysis, interpretation, and revision of the manuscript. All authors read and approved the final manuscript.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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