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Factors Influencing Mortality Under the Age of Five in Ethiopia

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Abstract: One important measure of a nation's level of development is its under-five mortality (U5M) rate. Notwithstanding notable reductions in the U5M rate, around 5.6 million children worldwide still pass away before turning five each year. According to the 2016 Ethiopian Demographic and Health Survey (EDHS) report, 67 children out of every 1,000 live births passed away before turning five years old. This study used data from the EDHS in 2016 to investigate factors associated with U5M in Ethiopia. The EDHS 2016 provided the information and 10,641 under-five children in total, weighted, were included in this study. Tables and graphs were used in the completion and reporting of descriptive statistics. To find important variables influencing U5M, a multi-level hurdle negative binomial model with an additional random effect was fitted. The following were found to be statistically significant factors for U5M in Ethiopia: maternal education status, place of delivery, husband/partners' educational status, place of residence, household wealth index, birth type, preceding birth interval, number of under-five children, sex of child, age of mother at first birth, source of drinking water, immunization coverage, child diarrhea status, ANC and PNC visits, and use of contraceptives. According to the findings, improving female education chances, resolving regional differences, and encouraging mothers to give birth in medical facilities would all have a significant role in reducing the burden of U5M. Furthermore, the results of this study support the idea that implementing multi-sectoral interventions to enhance access to drinking water, prenatal and postnatal care, spacing of births, child immunization programs, and contraceptive use will significantly lower Ethiopia's rates of U5M in the future. Policymakers and health planners should prioritize addressing preventable factors for under-five mortality in order to curtail and meet the Sustainable Development Goal (SDG) targets for under-five mortality in Ethiopia.

Keywords: Under-Five Children, Mortality, Multilevel Count Regression Analysis, EDHS 2016

1. Introduction

Around the world, it is anticipated that 5.2 million children under the age of five passed away in 2019 alone [1]. As for the U5M rate globally, it is said to have decreased by 60% between 1990 and 2019, from 93 deaths per 1000 live births to 38. Nevertheless, in 2019 there were 76 deaths for every 1000 live births in low-income countries—nearly 20 times higher than the 4 deaths for every 1000 live births in high-income countries. Infectious disorders, such as pneumonia, diarrhea, and malaria, have been found to account for over half of these deaths. These infections are preventable and treated and continue to be a major cause of mortality among children under five [2-4].

Many nations are on course to meet the 2030 target of at least 25 deaths per 1000 live-births, according to estimates from the Global Burden of Disease (GBD) 2017 SDG Collaborators. To do this, however, around thirty-one nations and territories would have to attain annual rates of reduction between 2015 and 2030 that are two to ten times greater than those observed between 1990 and 2015 [5].

Sub-Saharan Africa continues to have the highest rate of U5M worldwide, accounting for about half of all under-five deaths, even with significant advances over the past several decades. After Nigeria, India, Pakistan, and the Democratic Republic of the Congo, Ethiopia appears to have the fifth-highest rate of U5M worldwide in 2019 [6]. Ethiopia ranks sixth in the world in terms of the total number of deaths of children under five, with an estimated 472,000 children passing away before turning five each year [7].

Ethiopia's U5M rate dropped by two-thirds between 1990 and 2016, from 204 per 1000 live births to 58 per 1000 live births (MDG 4), but it contradicts achieving the target for Millennium Development Goal 4. Ethiopia's U5M rate is still greater than that of many low- and middle-income countries (LMIC), notwithstanding this accomplishment [8].

Ethiopia's consistent efforts to lower the death rate for children under five have made notable progress toward achieving MDG 4. But the loss is not evenly distributed, with significant regional differences observed across the nation [9]. MDG4 was met by Ethiopia and the six other nations for which Countdown commissioned case studies. MDG5 was met by China and Bangladesh, and four other nations exceeded this goal by greater than 75% [10]. The overall decline in U5M throughout the MDG era was largely attributable to national and international expenditures in efficient community-based interventions with greater equity of coverage. Additionally, evidence suggests that multi-sectoral policies and political, social, and economic issues interacted to affect child health [11].

The environmental, socioeconomic, biological, and demographic factors that have been demonstrated to affect survival chances account for variation in childhood death rates. Variations in exposure to risk variables linked to mortality that varies geographically may also be the cause of the regional and intra-national variance [12]. The social structures and community ecologies are linked to the dangers associated with mortality among children under five. Thus, knowledge of the regional distribution of infant deaths is essential for formulating critical policy [13].

Although this ambitious SDG is praiseworthy, there are worries that the new U5MR target under the SDGs may not be met if resources for maternal healthcare services, mother education programs, and expanding access to clean water and sanitation are not given enough priority [14]. This is due to the fact that earlier research by K. Rosicova has long demonstrated that the aforementioned elements, along with other socioeconomic concerns, are important determinants that interact to determine variations in U5MR both within and between nations [15].

Ethiopia has experienced a notable decline in U5M over the past 20 years. Between 2000 and 2016, the nation saw a decrease in the rates, from 166 to 67 deaths per 1000 live births [16]. Yet, there are still significant differences in Ethiopia's U5M rate. This study aimed to investigate the determinants of death among children under five years of age.

2. Methodology

2.1. Source of Data and Study Population

First, 645 clusters were chosen, of which 202 were urban and 443 were rural. Twenty-eight homes per cluster were chosen at random for the second stage. Moreover, 16,650 homes including 15,683 women aged 15 to 49 were chosen from 645 clusters. Questionnaires for households, women, and men make up the three sections of the EDHS 2016. An individual's questionnaire provided the study's data. Women between the ages of 15 and 49 who satisfied the eligibility requirements were interviewed in-person to gather data [17].

Under-five children made up the unit of analysis, and a total of 10,641 samples were chosen from 645 clusters throughout Ethiopia. The children's data used for this was gathered from mothers' retrospective information regarding their children who passed away before turning five in the five years leading up to the survey (2011–2016) [17].

2.2. Variables of the Study

2.2.1. Response Variable

The number of under-five child deaths per mother, which was defined as the deaths of children under the age of 60 months in the five years before to the survey, served as the response variable for this study.

2.2.2. Explanatory Variables

These predictor factors were chosen using data from the body of existing literature on various topics. This study's expected explanatory variables included health, environmental, demographic, and socioeconomic factors. All of these elements are, nevertheless, generally divided into two categories: factors at the individual and communal levels.

2.3. Multi-Level Count Regression Analysis

With an emphasis on layered sources of variability, multilevel analysis is an approach for analyzing data with complicated patterns of variability. The optimal method for analyzing multilevel data is one that captures both intragroup and intergroup relationships in a single study, where "group" denotes the higher-level units in the nesting hierarchy. It makes sense to visualize unexplained variation within groups and unexplained variation between groups as random variability by using probability models to describe the variability within and between groups. This implies that in an investigation of U5M within regions, unexplained variation within regions as well as variation between regions is considered a random variable. Multi-level models, a type of statistical model, can be used to examine such variation [18].

2.4. Multi-Level PH and HNB Regression Models

The Poisson Hurdle model is a two-component model that uses a truncated Poisson hurdle component for non-zero counts and a hurdle component to simulate zero versus non-zero counts [19, 20]. This is how the Poisson Hurdle model can be expressed.

$$p\left(Y_{ij}=y_{ij}\right)=\begin{cases}\pi_{ij} \text{ if } y_{ij}=0 \\ \left(1-\pi_{ij}\right)\frac{\exp\left(-\mu_{ij}\right)\mu_i^{y_{ij}}}{(1-\exp(-\mu)y_{ij}!} \text{ if } y_{ij}=1, 2, 3, \ldots\ 0\leq\pi_{ij}\leq 1 \\ \text{where, } \pi_{ij}=p(y_{ij}=0) \text{ and } \mu_{ij}=E(x_{ij}\beta)\end{cases} \quad (1)$$

where πij is the zero percentage parameters, μij is the mean, and Yij is the number of under-five children who die for the i[th] mother in the j[th] region.

Similarly, in the case of over-dispersion, the Poisson distribution above for the hurdle models can be substituted with the Negative Binomial Hurdle [21]. The response variable in our hurdle negative binomial (HNB) regression model has the Yij(i = 1, 2,....., n; j = 1, 2,....., m) has the distribution.

$$p\left(Y_{ij}=y_{ij}\right)=\begin{cases}\pi_{ij} \text{ if } y_{ij}=0\\ \left(1-\pi_{ij}\right)\dfrac{\Gamma\left(y_{ij}+\frac{1}{\alpha}\right)\left(1+\alpha\mu_{ij}\right)^{\frac{-1}{\alpha}}\left(1+\frac{1}{\alpha\mu_{ij}}\right)^{-y_{ij}}}{y_{ij}!\,\Gamma\left(\frac{1}{\alpha}\right)\left(1-\left(1+\alpha\mu_{ij}\right)^{\frac{-1}{\alpha}}\right)} \text{ if } y_{ij}>0\\ 0\le\pi_{ij}\le1\end{cases} \quad (2)$$

In this case, the mean is represented by parameters "μ≥0," while the dispersion parameter "α>0" is believed to be independent of variables.

The covariate vectors xij are related to both the mean μij and zero proportion πij parameters in the regression situation. Additionally, there's a good chance that responses from the same area will correlate. The linear predictor's ηij for the Poisson component and ϕij for the zero part integrate random effects uj and wj to account for the underlying correlation. The multi-level mixed regression model with Poisson Hurdle and Negative binomial Hurdle is

$$\eta_{ij}=\log\left(\mu_{ij}\right)=x_{ij}^{T}\beta+u_j \quad (3)$$

$$\phi_{ij}=\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right)=z_{ij}^{T}\gamma+w_j \quad (4)$$

where the associated (p+1) ×1 and (q+1) ×1 vectors of the regression coefficients are denoted by β and γ. Assuming independence, the random effects uj and wj have a normal distribution with a mean of zero and variances of σ_u^2 and σ_w^2 correspondingly. Depending on the assumed distribution (Poisson or negative binomial) of the count portion, the multi-level HR models are designated as MHPR and MHNBR, respectively, where regionally specific random effects are only taken into account in the count part (so wj = 0). MHNBR.ERE, for example, refers to models that have an additional random effect in the zero components, which is typically regarded as an additional random effect in the multi-level HR model [22, 23].

2.5. Model Selection

Using the DHARMa's uniformity test, the best model is chosen based on how well it fits the data. The uniformity test is used to determine if MHNBR or MZINBR (with or without additional cluster specific random effects) better fits the analyzed data, as mixed-effects HR and ZIR models are not directly comparable. The LR test is used to determine the significance of the regional variance component in the zero and count sections.

Various R packages were employed to examine various iterations of the NBR and PR models. Rizopoulos utilized his newly created "GLMMadaptive" software to fit mixed-effects ZIR and HR models. Using the residual diagnostics for hierarchical (multi-level/mixed) regression models found in Hartig's DHARMa (Diagnostics for Hierarchical Regression Models) package, the significance of the dispersion parameter, zero-inflation, and goodness-of-fit of the model (H_0: fitted model suits well for the data), also known as the uniformity test, were evaluated [24, 25].

3. Results

3.1. Descriptive Statistics

For this study, 10,641 children under the age of five were taken into account. Furthermore, only 3,065 out of 7,193 women who participated in interviews for information about under-five children had to deal with a total of 4,760 under-five child fatalities out of the total under-five children considered in the sample. This shows that 44.73% of the under-five children in the sample, out of all the children under five, passed away before turning five. Furthermore, according to the descriptive statistics, 42.61% of mothers lost at least one child, but 57.39% of moms did not experience the death of a child under the age of five.

Table 1 provided a basic summary of the effects of socioeconomic, demographic, health, and environmental factors on Ethiopia's under-five death rate. Approximately 17.36% of women in urban areas experienced U5M, which is significantly lower than the 32.88% of women living in rural areas. The Afar regional state had the highest variance in U5M per mother (40.96%), while the Addis Ababa administrative city had the lowest event (6.94%). Every other region, including Dire Dawa, was positioned in between the two percentages.

Theoretically, a mother's level of education plays a significant role in determining the survival of her under-five child. This viewpoint was backed by other literary works. As a result, mothers who had completed more schooling had a lower U5M rate (8.68%), while moms without any education had the highest U5M rate (35.24%). In relation to immunization coverage, U5M occurred in 17.23% of cases for mothers who finished their child's vaccinations, whereas 31.55% of cases involved moms who did not finish their child's vaccinations (Table 1).

Sanitation and the availability of drinking water were also evaluated; a better water supply lowers the death rate for children under five. Previous research has demonstrated that, in particular, reducing infant mortality occurs both directly—when fewer babies die from diarrhea caused by consuming tainted food or water—and indirectly—when caregivers are able to spend more time with their children rather than collecting water. In a similar vein, homes with better access to drinking water had less than one-fourth fewer under-five deaths per mother (21.20%), while homes without better access to water had 40.78% of under-five deaths. Table 1 illustrates that a higher percentage of under-five deaths occurred in homes with unimproved toilets (31.09%) compared to those with improved toilet facilities (18.02%).

Richer families are able to give their children better food, housing, and medical care, which increase the likelihood that the children will survive. This has been demonstrated in earlier research. In comparison to rich, richest, middle-class, and poorer wealth households, the study's five wealth index revealed that the poorest families had the highest U5M per mother, at 34.03% (Table 1).

Compared to private and public deliveries, the percentage of U5M per mother was greater in home deliveries, at roughly 33.38%. When compared to mothers who had more than four years prior to their previous birth interval (12.12%), mothers who had a preceding birth interval of less than two years had the highest likelihood of dying before the age of five (41.61%). In terms of the use of healthcare services, children whose mothers had not sought prenatal care throughout her pregnancy had the greatest proportion (32.91%) of deaths among those under five (Table 1).

Table 1. *Statistical measures (N = 10,641) showing the association between risk variables and U5M, EDHS 2016.*

Factors	Category	Number (N)	U5M		X^2 (p-value)
			Yes	U5M (%)	
Place of residence	Urban	2799	486	17.36	<0.001
	Rural	7842	2579	32.88	
Region	Tigray	1033	142	13.75	<0.001
	Afar	1062	435	40.96	
	Amhara	977	302	30.91	
	Oromia	1581	401	25.36	
	Somali	1505	516	34.29	
	Benishangul	879	339	38.56	
	SNNPR	1277	403	31.56	
	Gambela	714	238	33.33	
	Harari	605	150	24.79	
	Addis Ababa	461	32	6.94	
	Dire Dawa	547	107	19.56	
Age of mother at 1st birth	Less than 18	1458	602	41.29	<0.001
	18-24	8538	2339	27.40	
	Above 24	864	124	14.35	
Source of drinking water	Improved	6482	1374	21.20	<0.001
	Unimproved	4159	1696	40.78	
Access to sanitation / Latrine facility	Improved	1859	335	18.02	0.024
	Unimproved	8782	2730	31.09	
Religion	Orthodox	3082	746	24.21	0.217
	Muslim	5442	1737	31.92	
	Protestant	1862	489	26.26	
	Others	255	93	36.65	
Number of under-five children	One	4109	1263	30.74	<0.001
	Two-three	6240	1694	27.15	
	Four and above	292	108	36.70	
Mother's education level	No education	6838	2410	35.24	<0.001
	Primary/secondary	3077	592	19.24	
	Higher	726	63	8.68	
Sex of household head	Male	8383	2517	30.03	0.591
	Female	2258	548	24.27	
Household wealth index	Poorest	3993	1359	34.03	<0.001
	Poorer	1782	592	33.22	
	Middle	1466	426	29.06	
	Rich	1308	391	29.90	
	Richest	2092	300	14.34	
Contraceptive use	No	7888	2497	31.66	<0.001
	Yes	2753	568	20.63	
Marital status	Others	738	300	40.65	0.142
	Married	9903	2765	27.92	
Husband/partners' educational status	No education	5636	1890	33.53	<0.001
	Primary/secondary	3220	892	27.70	
	Higher	1785	283	15.85	
Mother's working status	House wife	7683	2231	29.04	0.627
	Had working	2958	834	28.19	
Husband/partners' occupation	Not working	917	312	34.02	<0.001
	Agricultural	1811	763	56.60	
	Professional/others	7913	1990	25.15	
Type of birth	Single birth	10363	2919	28.17	0.049

Factors	Category	Number (N)	U5M		X^2 (p-value)
			Yes	U5M (%)	
Birth order	Multiple birth	278	146	52.25	<0.001
	First born	2167	175	8.08	
	2nd or 3rd born	3338	598	17.91	
	4th born or higher	5136	2292	44.63	
Sex of child	Male	5483	1594	29.07	0.021
	Female	5158	1471	29.02	
Preceding birth interval	< 2 years	4579	1905	41.61	<0.001
	2-4 years	5039	1036	20.56	
	> 4 years	1023	124	12.12	
Place of delivery	Home	7155	2388	33.38	<0.001
	Public sector	3023	588	19.45	
	Private sector	463	89	19.22	
Immunization coverage	Incomplete	8598	2713	31.55	<0.001
	Complete	2043	352	17.23	
Child diarrhea status	No	9551	2464	25.80	0.041
	Yes	1090	601	55.14	
PNC visits	No	9007	2061	22.88	<0.001
	Yes	1634	1004	61.44	
ANC visits	No visits	8200	2699	32.91	<0.001
	1-4 visits	1465	262	17.88	
	5 and above visits	976	104	10.65	
Community women education	Low	6838	2410	35.24	<0.001
	High	3803	655	17.22	
Community vaccination status	Low	8152	2434	30.01	0.033
	High	2489	631	25.35	

Note: Number (N): the total number of mother in a given category, Yes: the number of mother who experienced U5M in a given category, U5M (%): percentage of mother who experienced under-five children death.

3.2. Test of Association with Individual Covariates

Table 1 above displays the results of the bivariate analysis of U5M and related predictor factors using the chi-square test of association. Ethiopia's regions with the highest rates of U5M were Afar (40.96%), Benishangul-Gumuz (38.56%), Somali (34.29%), Gambela (33.33%), SNNPR (31.56%), and Amhara (30.91%). The lowest rates were recorded in Addis Ababa (6.94%). As a result, region had a strong correlation (P-value < 0.001) with mortality among children under five.

With respect to residency, the U5M rate in rural areas (32.88%) was over double that of urban centers (17.39%). When it came to maternal age at first birth, moms who gave birth before the age of 15 were found to be responsible for 41.29% of under-five deaths (P-value < 0.001). Likewise, there was a significant difference in U5M according to mothers' educational attainment, with those with comparatively greater education having a decreased risk of U5M (P value < 0.001). The death rate for children under five decreases as partner education rises. Mothers whose husbands have no education reported an U5M rate of 33.53%; while, mothers whose partners have greater education reported a lower U5M rate of 15.53 percent (P value <0.001) (Table 1).

Furthermore, compared to the minimum proportion reported by wealthy households, substantial percentages of U5M were reported by households with the lowest economic status (P value <0.001). Additionally, Table 1 shows that husband occupation with a spouse in the agricultural sector had a significant U5M rate (P value < 0.0001).

Preceding childbirth order, birth type, sources of drinking water, access to restrooms, community women's education, and community vaccination status were all significant (P-value < 0.001) in the bivariate analysis, with the exception of religion, mother's occupation status, sex of the household head, and marital status. Furthermore, there was a higher likelihood of under-five child deaths in families with short birth intervals, mothers unable to use contraceptive methods, birth orders of four or higher, a high number of under-five children living in the home, multiple births, and no access to a toilet (Table 1).

3.3. Model Building

A variety of multi-level models were fitted, including hurdle Poisson, hurdle negative binomial, zero-inflated Poisson, zero-inflated negative binomial model, and hurdle Poisson. To make the model selection process easier, these models—both with and without intra-region correlation (ICC) consideration—were generated. For comparison, all models of U5M employed the same fixed set of explanatory factors. By evaluating the overall goodness of fit test, which determines whether model matches the data better, the final model is chosen using the DHARMa uniformity test.

In order to develop measures to enhance mother and child health care, policy makers, stakeholders, and donors investigate risk factors for the high under-five death rate. Finding those essential risk factors is aided by a suitable count regression model for U5M that takes into account a number of variables. In order to investigate the risk variables of U5M, this study evaluated one-part regression models (like PR and NBR) and two-part regression models (like ZIR or HR) with and without taking ICC into account. In comparison to the MZINBR, MHNBR and MZINBR.ERE models, the MHNBR.ERE model offers lower regional-specific variance components (as well as lower ICC) (Table 2).

***Table 2.** Lists the DHARMa Uniformity Test results and associated ICC for the models MHNBR.ERE, MZINBR, MZINBR.ERE, and MHNBR.*

Model	MZINBR	MZINBR.ERE	MHNBR	MHNBR.ERE
D-Statistic	0.025	0.042	0.020	0.016
p-value	0.231	0.001	0.320	0.626
σ_c^2	0.087	0.064	0.072	0.049
σ_z^2	-	1.248	-	0.620
$\rho_c = \sigma_c^2 / (\sigma_c^2 + \pi^2/3)\ in\ (\%)$	2.58%	1.91%	2.14%	1.47%
$\rho_z = \sigma_z^2 / (\sigma_z^2 + \pi^2/3)\ in\ (\%)$	-	27.50%	-	15.86%

3.4. Determinants of U5M in Ethiopia

As illustrated in Table 3, the subsequent sections of model revealed that the probability of being in the non-zero counts group was significantly correlated with the maternal education status, husband/partner's occupation, place of delivery, husband/partners' educational status, place of residence, wealth index of household and community women's education, birth type, preceding birth interval, number of under-five children, sex of child, age of mother at first birth, source of drinking water, immunization coverage, PNC and ANC visits, and use of contraceptives.

When all other covariates are held constant, the model indicates that mothers who were between the ages of 18 and 24 at the time of their first child's birth had a 33.7% (IRR = 0.663; 95%CI: 0.581, 0.749) lower risk of U5M. When all other characteristics were held constant, women who were 25 years of age or older had a 57.6% (IRR =0.423; 95%CI: 0.306, 0.588) lower probability of experiencing U5M than moms who were younger than 18 at the time of their first childbirth (Table 3).

The outcome also showed a negative correlation between U5M and the mother's educational attainment. After adjusting for other model variables, the mother's primary/secondary education level was linked to a 46% lower risk of U5M than a mother with no education (IRR=0.540; 95%CI: 0.240, 0.801), and her higher education level was linked to a 70.2% lower risk of U5M than a mother with no education (IRR=0.298; 95%CI: 0.123, 0.420). Conversely, when all other variables were held constant, the incidence of under-five-year-old deaths per mother of a female child was 73.3% (IRR=0.267; 95%CI: 0.112, 0.358) lower than that of male children (Table 3).

Another statistically significant risk for mortality among children under five was the household wealth index. Holding all other factors constant, the wealthiest wealth index was linked to a lower risk of U5M by 8% (IRR=0.920; 95%CI: 0.732, 1.150), 11.9% (IRR=0.881; 95%CI: 0.701, 1.110), 19% (IRR=0.810; 95%CI: 0.670, 1.121), and 34.9% (IRR=0.651; 95%CI: 0.471, 0.890) than the poorest wealth index, respectively.

The risk of death for children under five was significantly impacted by child immunization coverage. More specifically, compared to children who were only partially vaccinated, the risk of U5M dropped by 69% for fully vaccinated children (IRR = 0.310, 95%CI: 0.124, 0.563). Holding all other covariates constant, the risk of under-five death per mother increased by 4.16 times (IRR = 4.162, 95%CI: 3.870, 5.014) for every four under-five children in the home compared to one under-five child (Table 3).

Compared to mothers who did not get antenatal care, the risk of U5M was 67.3% (IRR = 0.327, 95%CI: 0.147, 0.487) lower among mothers who got antenatal care five times or more during their pregnancy. Additionally, women who had postnatal checks had a 70.8% lower risk of U5M (IRR = 0.292, 95%CI: 0.213, 0.412) than moms who did not receive postnatal exams. Compared to children born fewer than two years after the previous birth, the risk of U5M dropped by 73.3 percent (IRR = 0.267, 95%CI: 0.082, 0.356) among children born more than four years following the previous birth.

When compared to the first birth order, the risk of U5M for a mother whose children have a birth order of 4 or above rose by a factor of 2 (IRR = 2.010, 95%CI: 1.524, 3.001). Keeping all other variables equal, the study's conclusion demonstrated that women who used contraceptives had an approximately 80% reduced risk of U5M (IRR = 0.200, 95%CI: 0.012, 0.314) than moms who did not. This study's conclusion demonstrated that the risk of U5M was lower for mothers who gave birth in private and public health facilities, respectively, by 87.7% (IRR = 0.123, 95%CI: 0.017, 0.321) and 50.6 percent (IRR = 0.494, 95%CI: 0.234, 0.697) compared to mothers who gave birth at home. When compared to a single delivery, the incidence rate of U5M in multiple births was 1.29 (IRR = 1.290, 95%CI: 0.947, 1.554) times higher (Table 3). Furthermore, the results showed that, when all other factors were held constant, the risk of U5M increased by a factor 1.71 (IRR=1.713; 95%CI: 0.744, 3.943) for women with unimproved toilet facilities compared to women with improved toilet facilities.

The risk of under-five death is not just dependent on the vaccination status of a single kid; a community's greater vaccination rate may also have an impact on the risk of U5M for other mothers living in that community. Based on holding all other model variables constant, the findings showed that living in a community with a higher level of vaccination status was associated with an 82.2 percent (IRR = 0.178, 95% CI: 0.023, 0.302) lower risk of U5M when compared to a community with a lower level of vaccination status. Ultimately, it is evident that women's educational attainment affects their likelihood of experiencing under-five death. Moreover, a higher percentage of educated women in a community may have an impact on the risk of U5M for other women in that community. The results of the model, which held all other variables constant, showed that living in a community where women had a higher level of community education was associated with a 72.3 percent (IRR =0277, 95% CI: 0.051, 0.372) lower risk of experiencing U5M when compared to living in a community where women had a lower level of community education (Tables 3).

Table 3. *From the finalized model, the estimated regression coefficient (β), the IRR of experiencing U5M, and the OR of not experiencing U5M are displayed.*

Factors	Category	Count-part (Number of U5M) (truncated negative binomial with log link)					Zero-part (No U5M experience) (binomial with logit link)				
		β	IRR	95% CI for IRR		p-value	β	AOR	95% CI for AOR		p-value
Community level factors											
Place of residence	Urban^Ref										
	Rural	0.650	1.916	1.699	2.234	<0.001	-1.024	0.359	0.098	0.838	<0.001
Community women education status	Low^Ref										
	High	-1.281	0.277	0.051	0.372	<0.001	0.872	2.391	1.571	3.071	0.022
Community vaccination status	Low^Ref										
	High	-1.723	0.178	0.023	0.302	<0.001	1.241	3.459	1.004	4.210	0.442
Individual level factors (Mother, Child and Husband/partner's characteristics)											
Age of mother at 1st birth	Less than 18 ^Ref										
	18-24	-0.411	0.663	0.581	0.749	<0.001	0.530	1.699	1.026	1.856	<0.001
	Above 24	-0.858	0.424	0.306	0.588	<0.001	1.240	3.456	2.799	4.370	<0.001
Source of drinking water	Improved^Ref										
	Unimproved	0.670	1.954	0.795	2.140	<0.001	-1.711	0.181	0.046	0.454	<0.001
Toilet facility / latrine facility	Improved^Ref										
	Unimproved	0.538	1.713	0.744	3.943	<0.001	-1.650	0.192	0.025	0.587	0.334
Religion	Orthodox^Ref										
	Muslim	0.060	1.062	0.913	1.224	0.041	-0.428	0.652	0.362	1.021	0.012
	Protestant	0.030	1.030	0.873	1.223	0.671	-0.120	0.887	0.614	1.240	0.576
	Others	0.010	1.010	0.732	1.403	0.526	-0.110	0.896	0.702	1.325	0.256
Number of under-five children	One^Ref										
	Two-three	0.454	1.575	1.320	2.213	0.025	-0.671	0.511	0.421	0.812	0.043
	Four and above	1.426	4.162	3.870	5.014	<0.001	-1.023	0.359	0.236	0.501	<0.001
Mother's education level	No education^Ref										
	Primary / or secondary	-0.617	0.540	0.240	0.801	<0.001	0.456	1.578	1.232	1.973	<0.001
	Higher	-1.210	0.298	0.123	0.420	<0.001	1.001	2.721	2.014	3.450	<0.001
Sex of household head	Male^Ref										
	Female	0.203	1.225	1.034	1.525	0.422	-0.197	0.821	0.623	1.013	0.814
Household wealth index	Poorest^Ref										
	Poorer	-0.083	0.920	0.732	1.150	<0.001	0.040	1.041	0.889	1.235	0.027
	Middle	-0.127	0.881	0.701	1.110	<0.001	0.080	1.083	0.914	1.296	0.014
	Rich	-0.211	0.810	0.670	1.121	<0.001	0.070	1.073	0.769	1.351	<0.001
	Richest	-0.429	0.651	0.471	0.890	0.045	0.310	1.363	0.858	1.696	<0.001
Contraceptive use	No ^Ref										
	Yes	-1.610	0.200	0.012	0.314	<0.001	1.360	3.896	3.001	4.560	<0.001
Marital status	Others ^Ref										
	Married	0.419	1.52	1.062	2.194	<0.001	-0.021	0.979	0.801	1.021	0.244
Husband/partners educational attainment	No education ^Ref										
	Primary / or secondary	-0.070	0.932	0.806	1.084	<0.001	0.670	1.954	1.523	2.456	<0.001
	Higher	-0.641	0.527	0.376	1.027	<0.001	0.960	2.612	1.874	3.127	<0.001
Mother's working status	House wife ^Ref										
	Had working	0.136	0.873	0.673	1.107	0.049	-0.821	0.440	0.302	0.702	0.695
Husband / partners occupation	Not working^Ref										
	Agricultural	-0.075	0.927	0.806	1.084	<0.001	0.279	1.322	1.023	1.856	0.071
	Professional / others	-0.984	0.374	0.123	0.536	<0.001	0.752	2.121	1.409	2.912	0.013
Type of birth	Single birth ^Ref										
	Multiple birth	0.155	1.290	0.947	1.554	<0.001	-0.421	0.656	0.234	0.879	<0.001
Birth order	First born ^Ref										
	2nd or 3rd born	0.019	1.019	0.887	1.238	0.359	-0.121	0.886	0.564	1.051	0.793
	4th born or higher	0.698	2.010	1.524	3.001	<0.001	-0.879	0.415	0.236	0.745	<0.001
Sex of child	Male ^Ref										
	Female	-1.322	0.267	0.112	0.358	<0.001	0.945	2.596	1.689	3.201	0.024
Preceding birth interval	< 2 years ^Ref										
	2-4 years	-0.964	0.381	0.356	1.027	0.005	0.833	2.301	2.074	3.027	0.044
	> 4 years	-1.320	0.267	0.082	0.356	<0.001	1.131	3.099	2.563	3.741	<0.001

Factors	Category	Count-part (Number of U5M) (truncated negative binomial with log link)					Zero-part (No U5M experience) (binomial with logit link)				
		β	IRR	95% CI for IRR		p-value	β	AOR	95% CI for AOR		p-value
	Home [Ref]										
Place of delivery	Public sector	-0.705	0.494	0.234	0.697	<0.001	0.657	1.929	1.023	2.231	<0.001
	Private sector	-2.096	0.123	0.017	0.321	<0.001	0.921	2.511	2.051	3.041	<0.001
Immunization	Incomplete [Ref]										
coverage	Complete	-1.170	0.310	0.124	0.563	<0.001	1.230	3.421	2.560	4.125	<0.001
Child diarrhea status	No [Ref]										
	Yes	0.784	2.190	2.041	2.372	<0.001	-1.210	0.298	0.204	0.489	0.716
PNC visits	No										
	Yes	-1.230	0.292	0.213	0.412	<0.001	1.254	3.504	3.071	4.570	<0.001
	No visits [Ref]										
ANC visits	1-4 visits	-0.940	0.391	0.356	1.027	0.031	0.960	2.612	1.874	3.127	0.019
	5 and above visits	-1.117	0.327	0.247	0.487	<0.001	0.754	2.125	2.001	3.120	<0.001

Note: IRR Incidence Rate Ratio; OR Adjusted Odds Ratio; CI Confidence Interval; Coefficients (β); variable categories (Ref) indicates the reference group according to literature support.

4. Discussion

The purpose of this study was to evaluate the factors linked to Ethiopia's U5M rate. According to the study's findings, socioeconomic, demographic, environmental, and health-related factors all had an impact on U5M. The chosen model for the multi-level study determined the key factors influencing Ethiopia's U5M rate.

According to the study's findings, male children had a noticeably larger chance of passing away before turning five than did female youngsters. This is in line with what a cross-sectional study conducted in Bangladesh found [26]. It has been demonstrated that male infants are more susceptible to infectious diseases and so have a higher chance of dying within the first month of life. This could be because, in comparison to male neonates, female neonates have a reduced prevalence of respiratory illnesses due to their propensity to achieve early fetal lung maturity in the first week of life [27]. Compared to singleton births, multiple births result in a higher rate of child death. Due to rivalry in nutritional intake, multiple births have lower weights [28-31].

The results of this investigation demonstrated a correlation between mothers' educational attainment and a lower rate of U5M. Research from Zimbabwe and Indonesia, respectively, corroborated this conclusion [32, 33]. Studies conducted in Gilgel Gibe, Ethiopia, Columbia, Nigeria, Ethiopia, and Pakistan also shown that children born to illiterate women had an increased risk of child death [34-37]. Furthermore, an Indian study revealed that girls who receive an education had a lower risk of dying before the age of five [38]. Mothers who have received education may be more equipped to provide basic healthcare services such immunizations, disease treatment, preventive care, hygiene, and nutrition.

In addition, children with a birth spacing of less than two years are substantially more likely to die before age five than infants with a birth interval of more than four years. There is ample evidence to support the claim that longer birth intervals increase the likelihood that offspring will survive [39, 40]. According to a study, a short time interval between pregnancies can have an impact on mortality rates for children under five by depleting the mother's resources and spreading infectious illnesses [41].

Furthermore, the use of unimproved drinking water is linked to a higher risk of mortality among children under five, according to this study. It has been estimated that one of the major causes of more than 80% of child fatalities worldwide is a lack of access to safe water [6]. Additionally, a wealth of research conducted in underdeveloped nations has demonstrated that access to clean water and proper home sanitation are critical to the health and survival of children [42, 43].

According to this study, there is a decreased risk of U5M when deliveries take place in both public and private health facilities. This could mostly have to do with managing delivery issues that could increase the risk of U5M. In Ethiopia, there are relatively few health facilities offering cesarean section services. In the few that do exist, transportation issues encourage women to give birth at home, even in cases where facility-based delivery is feasible at a low cost [44]. Additionally, the study discovered that prenatal and postnatal care examinations improve the chances of survival for children under five. This aligns with the noteworthy correlation shown in the literature between prenatal and postnatal care and a decreased risk of U5M [45, 46]. It follows that children whose mothers do not obtain prenatal and postnatal care services may be more susceptible to various proximal causes of U5M than their peers, including congenital and infectious disorders.

U5M is strongly correlated with the number of children under five in a family. This result is in line with other research conducted in Sub-Saharan Africa on children born to non-contraceptive moms with big families, which is linked to a higher risk of U5M [47]. Children who have received vaccinations have a decreased mortality risk when compared to children who have not had vaccinations, and this conclusion is in line with other studies [28, 35, 48, 49].

U5M was substantially correlated with the mother's age during her first delivery. Previous research conducted in impoverished nations such as Ethiopia, Nigeria, and Bangladesh is in line with this discovery [29, 31, 47]. According to studies, child mortality rises with each unit increase in the mother's age [40]. These findings are similar. In other studies, mothers and children reared in urban regions had lower mortality rates because they had better access to healthcare and other essential services [35, 50]. The risk of U5M is higher for working moms than for non-working mothers. This result, however, conflicts with a Nigerian study that found employment lowered the risk of mortality for children under five [51]. Earning money from work enables the caregiver to get medical attention for the ailing child whenever necessary. However, having a job may result in fewer urgent trips to the hospital. Due to busy schedules, this could cause a delay in obtaining medical attention.

The investigation of the causes of Ethiopia's U5M rate has benefited greatly by this study. Therefore, in order to improve the standard of child care and the health of the beneficiaries—children—the study's findings will also be shared with stakeholders such as the Ministry of Health, the Department of Child Protection, the National Council for Children, UNICEF, WHO, and other non-governmental organizations.

5. Conclusion

The purpose of this study was to investigate the risk factors associated with U5M in Ethiopia after creating an appropriate multi-level count regression model that addressed the difficulties of over-dispersion, zero-inflation, and intra-cluster correlation (ICC). The following were found to be statistically significant factors for U5M in Ethiopia: maternal education status, husband/partner's occupation, place of delivery, husband/partners' educational status, place of residence, wealth index of household, birth type, preceding birth interval, number of under-five children, sex of child, age of mother at first birth, source of drinking water, immunization coverage, child diarrhea status, ANC and PNC visits, and use of contraceptives.

Therefore, the results confirm that mother educational attainment and the place of delivery had a noteworthy impact on mortality among children under five. Therefore, the results imply that improving female education chances, resolving geographic inequities, and motivating mothers to give birth in medical facilities will be essential components in the fight against the burden of U5M.

Lastly, the results of this study support the notion that implementing a multi-sectoral intervention aimed at enhancing the availability of clean drinking water, antenatal and postnatal care, spacing of births, child immunization coverage, and use of contraceptives will significantly lower Ethiopia's future rates of U5M. The study's conclusions will be useful in the design, development, and execution of policies aimed at lowering the death rate among children under five. Therefore, policymakers and health planners in Ethiopia should prioritize addressing preventable causes that contribute to under-five mortality in order to curtail and meet the Sustainable Development Goal (SDG) targets in this sector. To lower under-five mortality, the government and all stakeholders should focus on maternal and infant health care.

Abbreviations

AIC: Akaike Information Criterion
AOR: Adjusted Odds Ratio
ANC: Antenatal Care
BIC: Bayesian Information Criterion
CSA: Central Statistical Agency
DHARMa: Diagnostics for Hierarchical Regression Models
EDHS: Ethiopia Demographic and Health Survey
EHFP: Ethiopia Health and Family Planning
GBD: Global Burden of Disease
HNBR: Hurdle Negative Binomial Regression
HPR: Hurdle Poisson Regression
ICC: Intra-class correlation
IRR: Incidence of Relative Risk
MDG 4: Millennium Development Goal 4
MHNBR.ERE: Multi-Level Hurdle Negative Binomial Regression with Extra Random Effect
MHRP: Multi-Level Hurdle Poisson Regression Model
MPRM: Multi-Level Poisson Regression Model
MZINB: Multi-Level Zero Inflated Negative Binomial
MZINBR.ERE: Multi-Level Zero Inflated Negative Binomial with Extra Random Effect
PCV: Percentage Change in Variance
PNC: Postnatal Care
SDG: Sustainable Development Goal
SNNP: South Nation Nationalities and People
UN: United Nations
U5M: Under-five mortality
UNFPA: United Nations Population Fund
UNICEF: United Nations Children Fund
WHO: World Health Organization

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Declarations

Availability of Data and Materials

We have accessed the publically available data based on the available data access permission set by the agency under official web page (www.dhsprogram.com).

Ethics Approval and Consent to Participate

Our data source was the Ethiopia Mini Demographic and

Health Survey, 2016, which was collected at national level with written consents and ethical consideration during data collection by Ethiopian statistical Agency (CSA, https://www.statsethiopia.gov.et/). All methods were carried out in accordance with relevant guidelines and regulations.

Conflicts of Interest

The authors declare no conflicts of interest.

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