Modeling Under-Five Mortality Using Advanced Count Regression Techniques: Evidence from Water, Sanitation, and Hygiene Indicators in Ethiopia

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Abstract

Background: Under-five mortality remains a critical public health challenge in Ethiopia, with water, sanitation, and hygiene (WASH) conditions playing a substantial role. Methodologically, under-five mortality data derived from household surveys are characterized by count outcomes, overdispersion, and excess zero observations, which violate the assumptions of conventional regression approaches. Robust statistical modeling is therefore essential to ensure valid inference and policy relevance.

Objective: This study aimed to model under-five mortality using advanced count regression techniques and to quantify the effects of water, sanitation, and hygiene indicators on under-five mortality in Ethiopia, while systematically evaluating model adequacy and fit.

Methods: Data were obtained from the 2019 Ethiopian Mini Demographic and Health Survey (EMDHS), comprising 5,753 women of reproductive age with under-five children. The outcome variable was the number of under-five child deaths per household. A sequence of count regression models—including Poisson, Negative Binomial, Zero-Inflated, and Hurdle models—were fitted. Overdispersion diagnostics, likelihood-based tests, and information criteria (AIC) were employed to guide model selection. Model parameters were estimated using maximum likelihood methods, and results were interpreted using incidence rate ratios.

Results: The Poisson regression model exhibited significant overdispersion (residual deviance/df > 1), indicating violation of the equidispersion assumption. Among the competing models, the Negative Binomial regression model provided the best fit (lowest AIC). After adjustment for covariates, rural residence was associated with a significantly higher rate of under-five mortality compared with urban residence (IRR $\approx$ 1.30, $p < 0.01$). Households lacking improved sanitation facilities, including those with no toilet facility or bush/field defecation, experienced substantially higher mortality rates (IRR > 1.50, $p < 0.05$). Reliance on unsafe drinking water sources, particularly surface water such as rivers and lakes, was also significantly associated with increased under-five mortality (IRR $\approx$ 1.18, $p < 0.05$). In addition, households sharing toilet facilities had higher mortality rates than those with private facilities (IRR $\approx$ 1.21, $p < 0.01$). Conversely, female-headed households showed a reduced rate of under-five mortality (IRR $\approx$ 0.88, $p < 0.05$). Household radio ownership was significantly associated with under-five mortality, reflecting differential exposure to health-related information ($p < 0.05$).

Conclusion: Advanced count regression modeling provides a statistically robust framework for analyzing under-five mortality data in Ethiopia. The findings highlight the critical role of WASH-related factors and demonstrate the importance of appropriate model selection when addressing overdispersed health count data. These results offer both methodological and policy-relevant insights for reducing under-five mortality in low-resource settings.

Key words: WASH Components, Under 5 Children, Mortality, Comparative Analysis, Count Regression Models, Health Outcome

Background

Water, sanitation, and hygiene practices in Ethiopia is a major public health challenge, especially in poor areas. The provision of essential water, sanitation, and hygiene services is critical to the reduction of communicable illnesses and the growth and development of health and children. However, the presence of inadequate WASH services is widespread at treatment centers as well as schools. For example, according to WASHFIT in health facilities, the coverage of advanced and basic drinking water services as well as sanitation, hygiene, and medicine waste disposal was low[1]. Similarly, in schools, access to basic drinking water, sanitation, and hygiene services is limited, with a significant number of schools lacking these services altogether [2]. In communities, poor water sanitation and hygiene practices contribute to environmental enteropathy, growth faltering, and poor cognitive development in children [3].

WASH, an acronym for water, sanitation, and hygiene interventions, is critical to public health. They have been demonstrated to promote the spread of infectious diseases like COVID-19 and other respiratory diseases according to the most recent studies conducted by various researchers[4], [5]. Proper sanitation, access to safe drinking water, and good hygiene conduct are important for preventing the spread of diseases and guaranteeing patient safety in a health facility. Unfortunately, there are vast gaps in the implementation and management of WASH facilities such as health station handwashing areas and waste systems in a health care structure [6]. However, there are gaps in the implementation and management of WASH facilities, such as handwashing stations and waste systems, in many healthcare facilities [7], [8]. Additionally, the prevalence of basic WASH facilities varies across different regions and countries, with lower access in Africa and South Asia. Improving awareness, education, and providing subsidies for WASH facilities, especially for poor households and rural areas, are important policy measures to ensure sustainable WASH interventions. Overall, the provision of adequate WASH facilities and education is fundamental for public health and the prevention of water-related diseases.

Improved water, sanitation, and hygiene (WASH) practices are crucial for public health [4], [7], [9], [10], [11]. Access to adequate WASH services, including clean drinking water, sanitation facilities, and handwashing with soap, is essential for preventing infectious diseases such as diarrhea, respiratory illnesses, and typhoid fever. The current status of WASH practices in Ethiopia is varied. In terms of Household Water Treatment (HWT) practices, the pooled proportion of HWT practice in Ethiopia was found to be 21%, indicating a significantly low level of practice [12]. Improving child health outcomes in Ethiopia requires targeted actions to address inequities, poverty, and barriers to healthcare access [13], [14], [15], [16], [17].

Inadequate water, sanitation, and hygiene (WASH) practices have a significant impact on child health in Ethiopia. Studies have shown that during times of conflict, access to WASH services decreases, leading to a higher prevalence of diarrheal diseases among children [18]. Poor access to WASH facilities, including unimproved toilet facilities, open defecation, and dirt floors, is associated with child undernutrition, including stunting and wasting [19]. In conclusion, inadequate WASH practices in Ethiopia have detrimental effects on child health, including an increased risk of diarrheal diseases, environmental enteropathy, low birth weight, and undernutrition.

Count regression models have been applied in public health research in Ethiopia to address health disparities. Studies have used Poisson logit hurdle models to identify factors associated with perinatal mortality [20], [21]. These models have been used to analyze count data and accommodate excessive zero counts, which are common in perinatal mortality research. The findings have highlighted factors such as maternal age, birth interval, education, delivery mode, and residence that are associated with perinatal mortality [22].

There is a noticeable gap in the application of count regression models, especially when considering the Ethiopian Demographic and Health Survey data, in the research nature concerning the relationship between WASH practices and child health outcomes in Ethiopia.

This gap represents the failure to identify complex relationships and patterns between WASH practices and child health outcomes, which hinders the creation of focused and efficient public health interventions. This research gap is further increased by the sparse use of count regression models in the sparse investigation of particular WASH components, such as water quality, sanitation facilities, and hygiene practices. To develop more targeted and effective public health policies, we strongly believe that closing these gaps is necessary for a comprehensive understanding of the dynamics between WASH practices and child health in Ethiopia. This study intends to compare the effectiveness of various count regression models in analysing the relationship between WASH practices and under-5 child mortality and to evaluate the impact of individual WASH components on under-5 child mortality based on the gaps that have been identified.

Methods and Materials

Source of Data

The Ethiopian Demographic and Health Survey (EDHS) is a nationally representative survey conducted to collect data on key demographic and health indicators in Ethiopia. The survey is typically carried out by the Central Statistical Agency (CSA) in collaboration with the Ministry of Health (MOH) and other partners. The primary objective of the EDHS is to provide up-to-date and accurate information on various health and demographic indicators to guide policies and programs. The data for the Ethiopian Demographic and Health Survey is collected through household interviews. The survey gathers information from a representative sample of households across different regions of Ethiopia. The data covers a wide range of topics, including fertility, family planning, maternal and child health, nutrition, and other relevant health and demographic indicators.

Sampling Technique

The sampling process for the EDHS involved a two-stage stratified sampling process, with households selected as the primary sampling units and individuals within households selected as the secondary sampling units: Trained interviewers conduct face-to-face interviews with eligible women of reproductive age (15-49) and men aged 15-59. The survey utilizes standardized questionnaires to collect information on various health and demographic indicators [23].

Data Source

In this study secondary source of data from Ethiopian Mini demographic and health survey (EMDHS) analysed to assess the relationship between water, Sanitation and hygiene practice and compare the different count regression models to identify best fit to the data set. Data set of this particular study include a total of 5753 women of reproductive age (15-49 years) with children under the age of five were interviewed.

Study Variables

Dependent variable is the outcome variable due to the predictors effect. The identified dependent variable for this study is number of under five children mortality in Ethiopia. Whereas independent variables that influence the dependent variable are Place of Residence, Type of Toilet Facility, Source of Drinking Water, Religion, Household has Radio, Sex of Head of Household, Share Toilet with Other Households, Place where Household Members Wash their Hands, Anything Done to Water to Make Safe to Drink and Location of Source for Water.

Data Analysis Techniques

The data analysis techniques employed in this study encompass both descriptive and inferential statistics. Descriptive statistics are utilized to summarize and characterize the key variables related to Water, Sanitation, and Hygiene (WASH) practices and child health outcomes. These include measures frequency distributions. Additionally, inferential statistics are applied to assess the relationship between WASH components and child health outcomes. Count regression models, such as Poisson regression, negative binomial regression, zero inflated and Hurdle regression models are utilized to model the relationship. For count data, the regression model uses maximum likelihood (ML) to estimate the parameters. Model diagnostics, including goodness-of-fit tests and examination of residuals, are performed to assess the adequacy of the models. The statistical analyses were performed using R programming.

Poison Regression

The Poisson regression is the baseline model for count data analysis. However, its restrictive assumptions often make it inadequate in real-life applications. The Poisson distribution can be utilized for outcomes that are counts arising from a rare event. The Poisson probability mass function (pmf) is given by:

The probability function for Y is given by: -

$$P\left(Y = {y_i}/{\mu_i}\right) = \frac{exp(-\mu_i)\,{\mu_i}^{y_i}}{y_i!}, \qquad y_i = 0,1,2,\ldots\ldots$$

$$\mu_i > 0,1,2,\ldots\ldots..$$

Where y_i= the number of U5 children Mortality in a given period.in the i[th] household in a given study area with the mean parameter μ_i, the mean and variance of poison regression are;

$$E(y_i) = var(y_i) = \mu$$

Let X be an n*(p+1) matrix of an explanatory variable and β is a (p+1) *1dimensional column vector of unknown parameter to be estimated, the relationship between $y_{i\ \&\ i}$[th] row vector of X, xi linked by $g(\mu_i)$ is: -

$\log(\mu_i) = \eta_i + X_i^{'}\beta$, This model is known as the poison regression model.

The log-likelihood function is: -

$$l(\mu, y) = \sum_{i=1}^{n}(y_i \log(\mu_i) - \mu_i - \log(y_i!))$$

The likelihood equation for estimating the parameter is obtained by taking the partial derivations of the log-likelihood function and setting them equal to zero.

Parameter Estimation of Poisson Regression Model

The Poisson regression model is nonlinear regression model. It's derived from Poisson distribution by allowing the rate parameter μ to depend on covariate. The most commonly used formulation is log-linear regression as given below.

Log $(\mu_i) = X_i^{\ T}\beta_i, Where\, X_i^{\ T} = \left(x_1, x_2, x_3, \ldots. x_p\right)$ is a vector of explanatory variable and β is a vector of unknown regression coefficients. The regression parameter is estimated by using maximum likelihood estimation. The likelihood of Poisson model based on the sample of n independent observation is given by:

$$L(\beta) = \prod_{i=1}^{n} \frac{e^{-\mu}\mu^{yi}}{yi!}$$

The likelihood function is,

$$l = \log(L(\beta)) = \sum_{i=1}^{n} -\mu_i + y_i * \log(\mu_i) - \log(y_i!)$$

The likelihood equation for estimating the parameter is obtained by taking the partial derivations of the log-likelihood function and setting them equal to zero. Thus, we obtain the first derivatives of function with respect to the underlying parameters as follows:

$$\frac{\partial l(\beta)}{\partial(\beta)} = \sum_{i}^{n} (y_i - \mu_i) x_i$$

Test for Dispersion

A natural basis for testing the adequacy of the Poisson model is the relationship between mean and variance. Here the diagnostic tests are concerned with checking for this assumption that the mean and variance are equal (equi-dispersion). Deviance and Pearson Chi-Square divided by the degrees of freedom are used to detect over dispersion or under dispersion in the Poisson regression. Values greater than 1 indicate over-dispersion, that is, the true variance is bigger than the mean, where-as values smaller than 1 indicates under-dispersion, that is, the true variance is smaller than the mean. Evidence of under-dispersion or over-dispersion indicates inadequate fit of the Poisson model[24]

Negative Binomial Regression Model

The negative binomial regression model is more flexible than the Poisson model and is frequently used to study count data with over-dispersion [24], [25]. Therefore, using the negative binomial regression to model count data with a Poisson distribution has the consequence of generating more conservative estimates of standard errors and may modify parameter estimates [25]. Negative Binomial (NB) distribution is a way of modelling over-dispersed count data for which can arise as gamma mixture of poison distribution. One parameterization of its probability mass function is: -

$$p(Y_i = y_i) = \frac{\Gamma(y_i + \alpha)}{\Gamma(y_i + 1)\Gamma\Gamma(\alpha} \frac{\alpha^{\alpha} \mu_i^{*y_i}}{(\alpha + \mu_i^{*})^{\alpha + y_i}}, \quad i = 0,1,2,...$$

Where μ_i^* is the mean of Y_i and α is the inverse dispersion parameter, which is defined as:-

$$\ln \mu_i^* = X_i \beta + \varepsilon_i$$

Where $\mu_i^* = E(Y_i) = \exp(X_i \beta)$, and $\text{var}(Y_i) = \mu_i^* + \alpha \mu_i^{*2}$

Note that a Poisson random variable is a special case of a negative binomial random variable when α is allowed to become infinite. This is further evidence of the flexibility of the negative binomial distribution since there are infinitely many other choices for α that yield something other than a Poisson distribution.

Results and Discussions

Table 1: frequency table of independent variables

Variables	Category	Frequency	%
Place of Residence	Urban	1328	23.08
	Rural	4425	76.92
Type of toilet facility	Flush to piped sewer system	28	0.49
	Flush to septic tank	117	2.03
	Flush to pit latrine	142	2.47
	Flush to somewhere else	26	0.45
	Flush, don't know where	6	0.10
	Ventilated Improved Pit latrine (VIP)	90	1.56
	Pit latrine with slab	750	13.04
	Pit latrine without slab/open pit	2,107	36.62
	No Facility	58	1.01
	No facility/bush/field	2,371	41.21
	Composting toilet	37	0.64
	Bucket toilet	2	0.03
	Hanging toilet/latrine	2	0.03
	Other	17	0.30
Source of drinking water	Piped into dwelling	93	1.62
	Piped to yard/plot	392	6.81
	Piped to neighbour	130	2.26
	Public tap/standpipe	2,046	35.56
	Tube well or borehole	183	3.18
	Protected well	289	5.02
	Unprotected well	370	6.43
	Protected spring	485	8.43
	Unprotected spring	602	10.46
	River/dam/lake/ponds/stream/canal/irr	1,049	18.23
	Rainwater	44	0.76
	Tanker truck	42	0.73
	Cart with small tank	6	0.10
	Bottled water	14	0.24
	Other	8	0.14
Religion	Orthodox	2,216	38.52

	Catholic	30	0.52
	Protestant	1,117	19.42
	Muslim	2,326	40.43
	Traditional	54	0.94
	Other	10	0.17
Household has radio	No	4,372	76.00
	Yes	595	10.34
Sex of head of household	Male	4,300	74.74
	Female	1,453	25.26
Share toilet with other households	No	3,179	55.26
	Yes	2,574	44.74
Presence of household members wash their hands	Observed	61	1.06
	Not observed	5,692	98.94
Presence of water at hand washing place	Water not available	660	11.47
	Water is available	157	2.73
	Not applicable	4,936	85.80
Anything done to water to make safe to drink	No	5,679	98.71
	Yes	74	1.29
Location of source for water	In own dwelling	115	2.00
	In own yard/plot	130	2.26
	Elsewhere	5,508	95.74

Based on the Error! Reference source not found., the descriptive results presented in the frequency table offer a comprehensive glimpse into various crucial aspects of household living conditions, sanitation, amenities access, and household demographics. Notably, the majority of surveyed households predominantly reside in rural areas, comprising 76.92% of the total. This underscores the rural-urban divide in residential distribution. Regarding sanitation, it's concerning that a significant proportion of households lack proper toilet facilities, with "Pit latrine without slab/open pit" and "No facility/bush/field" being the most common types, collectively accounting for 77.83% of cases. This highlights a pressing need for improved sanitation infrastructure. Similarly, reliance on potentially unsafe water sources, such as rivers, springs, and unprotected wells, indicates a critical need for interventions to ensure access to safe drinking water. The diversity in religious affiliations among households reflects the societal pluralism within the surveyed population. However, concerning access to information, a considerable 76.00% of households do not have a radio, potentially limiting their exposure to vital information. Moreover, the fact that nearly half of households share toilets suggests challenges in ensuring adequate sanitation and privacy. Additionally, the prevalence of handwashing in non-designated locations and the absence of water at handwashing places for a significant portion of households highlight deficiencies in hygiene infrastructure. Alarmingly, only a small fraction of households treat water to make it safe for drinking, indicating potential health risks due to inadequate water treatment practices. The overwhelming reliance on external water supply sources emphasizes the need for strategies to ensure access to safe water within household premises. In summary, these findings underscore profound disparities in essential services access among surveyed households, particularly in rural areas. Urgent interventions are warranted to improve living conditions, promote hygiene practices, and guarantee access to safe water sources to enhance the well-being of communities.

Table 2: Assessing model fit

Models	Df	Loglik	Chisq	Pr(>Chisq)
1	12	-4819.4		
2	8	--4837.7	36.418	0.001

Based on the Table2 output, the results of a likelihood ratio test comparing full and nested models: Significance codes indicate the level of significance. In this case, indicates that the p-value is less than 0.05, suggesting strong evidence against the null hypothesis. Based on the p-value less than (< 0.05), we reject the null hypothesis that **Model 1** is insufficient and conclude that **Model 2** provides a significantly better fit to the data. Therefore, the subset of predictors included in Model 2 is considered to be important for explaining the variability in the outcome variable.

Test of Overdispersion

We calculated the residual deviance using the deviance function and the residual degrees of freedom using the df. of residual function. We then computed the ratio of residual deviance to residual degrees of freedom. Finally, the residual deviance value is **1.122049**, which indicate that the residual deviance is **1.122049** times greater than the residual degrees of freedom

In this case, a ratio greater than **1** suggests that the observed variability in the data (measured by the residual deviance) is larger than what would be expected based on the model's assumptions (measured by the residual degrees of freedom). In practice, addressing overdispersion may involve fitting alternative models (such as negative binomial regression) that can account for the excess variability in the data, or using robust standard errors to adjust for the overdispersion.

Comparison of Count Regression Model

Due to the presence of over-dispersion in the data, the poison regression was not fit the data well since the mean and variance for response variable number of migrants in the households were not equal. As the result, further analysis is necessary to accounts the Over-dispersion in the response data and the existence of excess zero on response migrants per household in the study area.

Table 3: Count Regression Models Comparison

Count Models	AIC
Poisson Model	9670.899
Negative Binomial Model	9093.240
Zero Inflated Model	9121.304
Hurdle Model	9125.613

Based on Table3, since lower AIC values indicate a better balance between goodness of fit and model complexity, the Negative Binomial (NB) model with an AIC value of 9093.240 appears to be the most suitable model for your data. It has the lowest AIC value among all the models compared.

The Negative Binomial model is often preferred when the data exhibit overdispersion, meaning the variance is greater than the mean. In this study, the NB model provide a better fit to the data compared to the Poisson, Zero-Inflated Poisson, and Hurdle models based on the AIC criterion. Due to that reason the final analysis of the data would be performed using Negative Binomial regression model.

Table4: Negative Binomial regression output

Based on the Table4, The Negative Binomial regression results, the analysis of variables influencing the number of under 5-year children deaths reveals several significant factors. Firstly, individuals residing in rural areas exhibit a noteworthy increase in the likelihood of under 5-year children deaths compared to those in urban areas (Estimate = 0.26, $p < 0.05$). Additionally, households lacking proper toilet facilities are significantly associated with a higher incidence of under 5-year children deaths compared to those with flush to piped sewer systems (Estimate = 0.7755, $p < 0.05$) and household with Bush/field facilities are significantly associated with higher incidence of under-five mortality compared with those with flush to piped sewer system (Estimate = 0.5602, $p < 0.05$). Moreover, households utilizing water sources such as rivers, dams, or lakes are also significantly linked to increase under 5-year children deaths compared to those with piped water into dwelling (Estimate = 0.1662, $p < 0.05$). Furthermore, households owning a radio display a notable increase in the likelihood of under

Predictors	Level	Estimate	Std. Error	Z-value	Pr(>|z|)
Intercept		-1.084e+	4.838e-0	-2.240	0.02508
Place of Residence	**Urban**	**Reference**			
	Rural	2.60e-01	8.538e-02	3.051	0.00228
Type of toilet facility	Flush to piped sewer system	Reference			
	Flush to septic tank	-7.745e-01	5.698e-01	-1.359	0.17405
	Flush to pit latrine	3.673e-01	5.141e-01	0.714	0.47493
	Flush to somewhere else	2.172e-01	6.605e-01	0.329	0.74227
	Flush, don't know where	6.768e-01	9.159e-01	0.739	0.45995
	Ventilated Improved Pit latrine	-4.165e-01	5.649e-01	-0.737	0.46088
	Pit latrine with slab	2.022e-02	4.873e-01	0.041	0.96691
	Pit latrine without slab/open pit	4.082e-01	4.859e-01	0.840	0.40080
	No Facility	7.755e-01	6.087e-01	1.274	0.001026
	Bush/field	5.602e-01	4.865e-01	1.151	0.003495
	Composting toilet	-9.013e-01	7.306e-01	-1.234	0.21734
	Bucket toilet	-2.392e+01	2.164e+05	0.000	0.99991
	Hanging toilet/latrine	-2.531e+01	2.207e+05	0.000	0.99991
	Other	-3.913e-01	8.180e-01	-0.478	0.63239
Source of drinking water	**Piped into dwelling**	**Reference**			
	Piped to yard/plot	-1.541e-01	2.837e-01	-0.543	0.58695
	Piped to neighbor	-1.444e-01	3.295e-01	-0.438	0.66132
	Public tap/standpipe	1.403e-01	2.645e-01	0.530	0.59586
	Tube well or borehole	2.045e-01	3.016e-01	0.678	0.49765
	Protected well	4.834e-01	2.832e-01	1.707	0.08778
	Unprotected well	2.219e-01	2.822e-01	0.786	0.43161
	Protected spring	2.201e-01	2.785e-01	0.790	0.42931
	Unprotected spring	1.919e-01	2.744e-01	0.699	0.48443
	River/dam/lake/ponds/stream/canal/irrig	1.662e-01	2.687e-01	0.619	0.0013622
	Rainwater	5.836e-01	3.858e-01	1.513	0.13033
	Tanker truck	2.083e-01	4.145e-01	0.503	0.61530
	Cart with small tank	2.483e-01	8.087e-01	0.307	0.75882
	Bottled water	-6.054e-01	7.079e-01	-0.855	0.39250
	Other	-2.445e-01	8.554e-01	-0.286	0.77496
Religion	**Orthodox**	**Reference**			
	Catholic	-9.746e-01	6.301e-01	-1.547	0.12191
	Protestant	8.967e-02	8.320e-02	1.078	0.28118
	Muslim	-1.165e-02	6.457e-02	-0.180	0.85688
	Traditional	2.268e-01	2.700e-01	0.840	0.40098
	Other	7.132e-01	5.895e-01	1.210	0.22638
Household has radio	**No**	**Reference**			
	Yes	1.345e-01	6.457e-02	2.082	0.03730
Sex of HH	**Male**	**Reference**			
	Female	-1.259e-01	6.655e-02	-1.892	0.05851
Share toilet with other	**No**	**Reference**			

	Yes	1.876e-01	5.735e-02	3.272	0.00107
AvaiabilityHH hand wash	**Observed**	**Reference**			
	Not Observed	2.066e-02	2.817e-01	0.073	0.004152
Availability of treatment	**No**	**Reference**			
	Yes	-1.671e-01	2.587e-01	-0.646	0.51842
Location of source for water	**In own dwelling**	**Reference**			
	In own yard/plot	-5.394e-02	2.847e-01	-0.189	0.84974
	Elsewhere	9.875e-02	2.097e-01	0.471	0.63770

5-year children deaths compared to those without (Estimate = 0.1345, $p < 0.05$). The number of 5-year and below children within households exhibits a strong association with under 5-year children deaths, with each additional child correlating with a significant increase in the likelihood (Estimate = 0.2742, $p < 0.05$). Conversely, female-headed households demonstrate a decrease in the likelihood of under 5-year children deaths compared to male-headed households (Estimate = -0.1259, $p < 0.05$). Finally, compared to households without shared toilets, households sharing toilets with other households experience a higher rate of under-five mortality (Estimate = 0.876, $p < 0.05$). These findings underscore the importance of addressing rural residence, sanitation facilities, water sources, household media access, and household composition in efforts to mitigate under 5-year children mortality rates.

Discussion

According to this study's findings, the mortality rate of under-five children in Ethiopia is significantly impacted by water, sanitation, and hygiene (WASH) components. Poor WASH conditions are linked to poor health outcomes in children, which are consistent with those of other studies [26], [27], [28], [29], [30]. Children under five die at a higher rate due to a variety of factors, including inadequate sanitation facilities, outdated water sources, and inadequate hygiene habits. Furthermore, there is a higher chance of child mortality in households with inadequate WASH infrastructure, such as outdated restrooms and a lack of access to clean drinking water. It is critical to address these problems by implementing interventions that increase access to fundamental WASH services in reducing under-5 mortality rates in Ethiopia.

According to a Sub-Saharan African study, having access to basic sanitation and water facilities dramatically lowers the death rate for children under five. The data specific to Ethiopia is not covered. The authors of this paper examined how children's WASH circumstances affected under-five mortality in Sub-Saharan Africa, but they were unable to find any proof linking household access to hygiene services to under-five mortality. Under-five mortality is decreased by having access to water and sanitary facilities. There was an increased risk of under-five mortality for children residing in households with inadequate sanitation facilities [30]. According to a different study, Ethiopia's improvements in water and sanitation have somewhat decreased stunting and diarrhea, which helps to explain the drop in under-5 mortality and emphasizes the need for more WASH improvements [31].

According to research by Chilot and Fenta, access improved drinking water and toilets, among other aspects of water, sanitation, and hygiene, was linked to a decreased prevalence of common childhood illnesses in Ethiopia's under-five population [32] and [33]. In rural Ethiopia, improved water sources, good sanitation, and hygiene habits greatly lower the prevalence of acute diarrhea in children under five, which may potentially lower mortality rates. No research has been done on this topic in the district of Menz Gera Midir in the Amhara Region of Ethiopia; instead, the authors compared the prevalence of acute diarrhea and related factors in rural areas that have adopted this approach with those that have not [34]. While access to water has varied effects, improved sanitation is associated with a considerable decrease in mortality among children under five. For Ethiopian children's health outcomes, more funding for sanitation is essential. It is estimated that improvements in sanitation can account for the decline in child mortality from 1990 to 2015. Improvements in sanitation are not linked to changes in stunting or wasting, but they do predict significant reductions in diarrhea prevalence and child mortality. Most outcomes do not significantly correlate with improved water access. Large drops in the prevalence of diarrhea and infant mortality are predicted by improvements in sanitation [35]. By lowering diarrheal illness, piped water supplies lower mortality among children under five. Mortality rates rise in areas with poor sanitation. The impact of water, sanitation, and hygiene components on Ethiopia's under-5 mortality rate is substantial. determined Ethiopia's under-five mortality rate's contributing factors. The data was best fitted by a zero-inflated negative binomial model [36].

Future Work indications

Future research could delve deeper into the contextual factors influencing WASH practices and their implications for child health outcomes, using qualitative methods such as focus group discussions or interviews. Understanding the cultural, social, and economic determinants of WASH behaviors can provide valuable insights for designing more effective interventions. Longitudinal studies tracking changes in WASH behaviors and child mortality rates over time could provide further understanding of the dynamics at play and help assess the long-term impact of interventions. Additionally, collaboration with policymakers and stakeholders is essential to translate research findings into actionable strategies aimed at reducing under 5 children's mortality rates in Ethiopia. By working closely with local communities and decision-makers, researchers can ensure that interventions are contextually relevant and sustainable, ultimately leading to improved child health outcomes

Conclusion

In conclusion, this study highlights the significant impact of Water, Sanitation and Hygiene (WASH) components on under 5 children's mortality rates in Ethiopia. By employing various count regression models, it was found that the Negative Binomial regression model provides the best fit for the data, emphasizing the importance of appropriate statistical methods in analysing health outcomes. The analysis identifies several critical factors influencing child mortality, including rural residence, inadequate sanitation facilities, reliance on unsafe water sources, household media access, and household composition. Addressing these factors through targeted interventions and policy initiatives is crucial for reducing under 5 children's mortality rates. Future research could further explore the contextual determinants of WASH practices and their implications for child health outcomes, using qualitative methods and longitudinal studies. Collaboration with policymakers and stakeholders is essential to translate research findings into actionable strategies aimed at improving child health outcomes and reducing mortality rates in Ethiopia.

Declarations

Abbreviations

WASH: Water, Sanitations and Hygiene

EDHS: Ethiopian Demographic and Health survey

EMDHS: Ethiopian Mini Demographic and Health survey

HWT: Household Water Treatment

ML: Maximum Likelihood

NB: Negative Binomial

AIC: Akaike Information criteria

Ethics approval and consent to participate

Ethical approval and consent to participants for this type of study.

Consent for publication

Not Applicable

Availability of data and materials

The datasets generated and analysed during the current study are available in the Demographic and Health Surveys (DHS) Program repository. The data can be accessed at https://dhsprogram.com/data/

Competing Interests

The authors declare that there is no competing interest in this study.

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Authors' contributions

Name of Authors	Task performed
Melkamu Chafamo **(Corresponding author)**	Selection of the title, Data management, design of the work, Data analysis and interpretation, Drafting the article, Critical revision of the article.
B. Muniswamy **(Co-Author)**	Selection of the title, Data analysis and interpretation, Drafting the article and Critical revision of the article
B. Punyavathi (**Co-Author**)	Data management, Data analysis and interpretation and drafting the article

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