Factors Affecting Under-five Mortality in Selected Districts of Nepal: A Cross-sectional Study Using Logistic Regression

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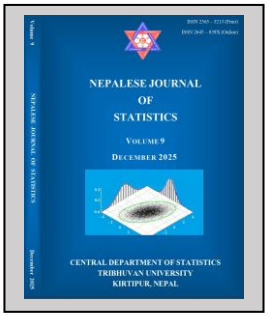

ABSTRACT

Background: Despite the considerable improvement in reducing under-five mortality (U5M) over time, Nepal has been experiencing a slow decline in under-five mortality rates and stationary neonatal mortality rates in recent years. It reflects the ongoing challenges to meet the Sustainable Development Goals target of reducing the under-five mortality rate to 25 or fewer per 1,000 live births by 2030. Identifying the factors of U5M may be useful for designing targeted and area-specific interventions to accelerate the reduction of childhood mortality.

Objective: This study is conducted to identify the factors affecting the survival status of under-five children in selected districts of Nepal.

Materials and Methods: Primary data collected through a structured questionnaire were analyzed in this study. In total, 205 live-born children younger than five years before data collection from the selected areas were included in this study. To explore the factors affecting the survival status of under-five children, a multivariable logistic regression model (MLRM) was fitted. Likelihood ratio test, Hosmer-Lemeshow goodness of fit test were used to examine the fit of the model. Predictive power of the model was evaluated with the Receiver Operating Characteristic curve.

Results: After fitting the MLRM, different factors were found to be significantly associated with the survival status of under-five children. Muslim mothers as compared to Brahmin and Chhetri (AOR = 10.21, 95% CI: 1.42 - 73.30), the unhealthy child at the time of birth than those who were healthy (AOR = 19.25, 95% CI: 2.00 - 185.04), mothers who had no education as compared to those having secondary and higher level (AOR = 14.59, 95% CI: 1.65 - 128.88), children who had smaller or larger than average size at birth in contrast to those having average size (AOR: 3.49, 95% CI: 1.02 - 12.00), children from households that uses wood as a cooking fuel relative to those using LPG (AOR = 32.20, 95% CI: 7.78 - 133.22) more likely to experience U5M. Whereas, children whose fathers had no education, compared to those having secondary and higher education, had a lower risk of U5M (AOR = 0.048, 95% CI: 0.004 - 0.47).

Conclusion: Ethnicity of mothers, health status of child at the time of birth, mother's education, size of child at birth, father's education, and types of cooking fuel were the key factors related to

survival status of under-five children. Advancing women's education to at least the secondary level, encouraging and supporting communities for the use of clean energy, and strengthening the systems that provide a continuum of care and adequate treatment for infants born with vulnerable health are the important tasks to reduce U5M in the study areas.

Keywords: Multivariable logistic regression, Nepal, survival status of under-five children, under-five mortality.

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INTRODUCTION

The analysis of under-five mortality (U5M) provides valuable insights into assessing the country's demographic status, socioeconomic development, and overall quality of life (Ministry of Health [MoH], et al., 2023). U5M remains a major global public health concern worldwide and is recognized as a key target within the Sustainable Development Goals (SDGs). In 2023, global estimates indicate that 4.8 million children died before age five, a notable advancement compared with the 10.1 million under-five deaths estimated in 2000. This substantial improvement indicates that the global under-five mortality rate (U5MR) has fallen by more than half since 2000. This progress corresponds to a decline in U5MR from 77 deaths per 1,000 live births in 2000 to 37 deaths per 1,000 live births in 2023, representing a 52 percent reduction across the interval. This reduction in mortality rate reflects combined efforts undertaken by the governments and various organizations throughout the Millennium Development Goals (MDGs) period 2000-2015, and in the subsequent period of the SDGs (United Nations Children's Fund [UNICEF], 2025). However, despite this significant achievement, the global U5MR remains considerably higher than the SDG 3.2 target of 25 deaths per 1,000 live births.

Large disparities in U5MR continue to exist across countries and regions. For instance, the U5MR ranges widely, from 115 deaths per 1,000 live births in the highest mortality country in the world to the country with just 1.4 deaths per 1,000 live births in 2023. The 2023 estimates indicate that Sub-Saharan Africa had the highest regional U5MR with 69 deaths per 1,000 live births. Oceania (excluding Australia and New Zealand) recorded the second-highest regional U5MR at 37 deaths per 1,000 live births, while Southern Asia ranked third with 34 deaths per 1,000 live births. Moreover, in 2023, over 80% of global U5M occurred in Sub-Saharan Africa and Southern Asia, implying that four out of five child deaths were concentrated in these two regions (United Nations Children's Fund [UNICEF], 2025). Neonatal mortality constitutes a substantial proportion of U5M in Southern Asia, which is mostly related to complications at birth, preterm birth, and congenital disorders.

Nepal has achieved a significant reduction in U5M over recent decades, particularly following the MDGs period and continuing into the SDGs era. The U5MR declined from 162 deaths per 1,000 live births in 1990 to 38 deaths per 1,000 live births in 2014, and then to 33 per 1,000 live births in 2022 (Ministry of Health [MoH], et al., 2023; National Planning Commission [NPC], 2016). This progress reflects the sustained implementation of periodic plans and strategies, supported by effective interventions addressing major causes of mortality through community and national programs. The success of these efforts relied on significant financial investment from the government and national and international agencies (World Health Organization [WHO] & Ministry of Health and Population [MoHP], 2015). Although U5M declined, the stagnant and high neonatal mortality remains a major obstacle to meeting the SDG goal of reducing U5MR to 25 or lower per 1,000 live births by 2030.

To accelerate the decline of U5MR, it is essential to identify the factors of U5M and use them to formulate effective health policies and programs. A systematic review examining the determinants of U5M revealed that several factors substantially influence the survival of under-five children; however, such factors vary according to different circumstances (Bhusal & Khanal, 2022). Studies in Nepal using the Demographic and Health Survey (DHS) data have identified several factors influencing U5M, including wealth status of household, maternal education, use of tetanus toxoids vaccines during pregnancy, contraceptives use, ecological region, number of children ever born, source of drinking water, maternal smoking, preceding birth interval, and birth order number (Ghimire et al., 2019; Bhusal & Khanal, 2025; Sreeramareddy et al., 2013). The findings of such studies, which utilize a national-level survey, offer broad and representative estimates; however, their aggregate results may mask important variations across communities, ecological regions, and socio-cultural contexts. On the other hand, a small-scale survey focuses on a smaller and more targeted population, which allows for a deeper understanding of local determinants, subtle behavioral patterns, and context-specific insights into the area of study. Therefore, this study was conducted to identify the major factors affecting the survival status of under-five children, particularly in the selected areas.

MATERIALS AND METHODS

Study area and setting

The U5M is a relatively rare event. It is not uniformly distributed across different geographical areas, which makes it difficult to collect a sufficient sample of under-five deaths from a specific region to examine the associated factors. This research was undertaken in the Dolakha, Arghakhanchi, and Banke districts of Nepal. These districts were chosen purposively for data collection. Dolakha was selected from the Mountain region. Data regarding the survival of under-five children were obtained from the mothers living in different communities across Bhimeshwor municipality, Tamakoshi, Kalinchowk, Bigu, and Gaurishankar rural municipalities.

The study included the Arghakhanchi district, located in the Hilly region. Interviews were administered among sample mothers within Sandhikharka municipality. Banke district was selected from the Terai region. It represents one of the Terai districts with a high burden of U5M.

Information was gathered from the mothers of under-five children living in Nepalgunj sub-metropolitan city, as well as in Khajura, Janaki, and Duduwa rural municipality. Figure 1 shows the location of districts, municipalities, and rural municipalities of the respondents who participated in the study.

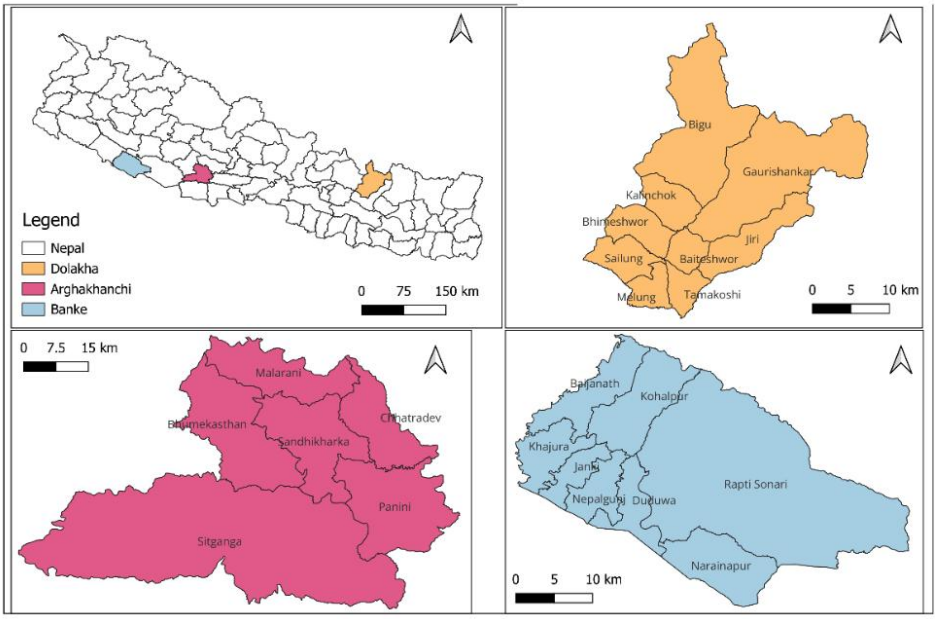


Fig. 1. Geographical locations of the study areas in the map of Nepal.

Study design

This study utilizes primary data collected by researchers. It is a cross-sectional study conducted to explore the factors affecting the survival status of under-five children in selected areas of Nepal.

Sampling technique

Considering the low prevalence of the outcome variable and the absence of a sampling frame for the number of under-five live births and deaths, a purposive sampling method was adopted in this study. District-level aggregate data on live births and under-five deaths were obtained from the Health Management Information System (HMIS) records for the year 2077/078 of the Ministry of Health and Population (MoHP), Nepal to identify the cases of U5M across districts. Selecting a single district or region for data collection was not feasible due to the small number and dispersed cases of U5M reported in a given year. Therefore, to ensure an adequate number of U5M cases, Dolakha, Arghakhanchi, and Banke districts were purposively selected, representing the Mountain, Hill, and Terai regions, respectively. The prevalence of U5M was 0.063 in Dolakha, 0.0117 in Arghakhanchi, and 0.00296 in Banke. Respondents were selected using purposive sampling in

coordination with the staff of health posts and Female Community Health Volunteers (FCHVs) across municipalities and rural municipalities of the three districts.

Determination of sample size

According to HMIS records for 2077/078, Dolakha ranked third in U5M prevalence with 0.063 after Ilam and Sindhuli. Given that Dolakha was part of the sample, the sample size was determined by using its U5M prevalence as follows:

The proportion of under-five deaths (P) = 0.063; Level of significance (α) = 0.05; Power ($1-\beta$) = 0.8; The margin of error (d) = 0.05. The following relation is used to compute the sample size.

$$n = \frac{\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2 P(1-P)}{d^2}$$

$$= \frac{(1.96+0.843)^2 \times 0.063\ (1-0.063)}{(0.05)^2}$$

$$= 185.52 \approx 186$$

Considering 10% non-response, the sample size (n) = 205. At the time of data collection, we did not encounter the case of non-responses since the researcher personally visited the respondents at their house with the volunteer support of staff at the health posts and FCHVs. All the equested respondents voluntarily participated in the survey and provided the necessary information.

Data collection

A structured questionnaire was developed after reviewing the literature on childhood mortality. The questionnaire included six different sections: demographic characteristics, parental characteristics, child-related information, socioeconomic status, and healthcare-related questions. Most of the questions were adapted from the Demographic and Health Survey (DHS) survey instruments, and some were included after taking insights from a systematic review of literature on factors affecting U5M, which ensures content validity. Expert opinions were also taken to assess the relevance of all structured questions. The use of standardized and already validated questions supports the reliability of measurements. The questionnaire was prepared in Nepali and English. All women aged 15-49 and giving live birth within five years before the survey in the selected districts constitute the population of this study. Written informed consent was obtained from the respondents before the interview, allowing them the right to refuse participation at any time during the interview. Retrospective information was collected from mothers about children who were born alive during the five years before the survey. The staff at the health posts and FCHVs facilitated the researcher reaching the respondents, and especially communicating with the mothers whose children had died before attaining the fifth birthday, and with those who did not feel comfortable speaking Nepali. The data were collected through face-to-face interviews with mothers about live and dead children, and responses were documented in hardcopy form. Data collection started on 25 April 2023 and was completed on 10 July 2023.

Outcome variable

The outcome variable for this study is the survival status of the under-five children, classified as alive or dead (0 = alive, 1 = dead) after live birth.

Explanatory variables

The set of explanatory variables were identified from the literature (Bhusal & Khanal, 2022). Several factors related to U5M across different circumstances were selected as a potential set of explanatory variables. These factors were related to the socioeconomic status, maternal and paternal characteristics, child-related, and utilization of healthcare-related variables, including some other contexts. A detailed list of these variables with their levels is shown in Table 1. The categorization of each covariate was guided by existing literature on childhood mortality, its relevance for meaningful interpretation, and the exploratory analysis of the dataset.

Statistical analysis

SPSS 27 was used for data entry and coding. Further analysis of the data was performed using Stata 18 and R (version 4.4.3). The consistency of the data was verified through frequency tables and cross-tabulations before analyzing the data. Both descriptive and inferential statistical methods were employed to analyze the data. The status of U5M across various levels of the covariates was assessed using descriptive analysis. The outcome variable of the study was dichotomous in nature, so the multivariable logistic regression model (MLRM) was used to analyze the data. At the beginning, bivariate logistic regression was used to examine the association between outcome and explanatory variables. The odds ratios (ORs) and their 95% confidence intervals (CIs) were computed. Only those explanatory variables having p-values less than 0.05 were selected as candidate variables for multivariate analysis. Multicollinearity among those candidate explanatory variables was assessed using the generalized variance inflation factor (GVIF). GVIF is a generalization of the variance inflation factor (VIF), which is appropriate for models containing categorical as well as a mix of categorical and continuous explanatory variables. To account for the different levels of categorical variables, the adjusted measure $GVIF^{1/(2\times df)}$ is recommended rather than GVIF, where *df* represents the number of dummy variables associated with a categorical variable. As a general rule of thumb, values greater than or equal to 1.58 indicate potential multicollinearity concerns in logistic regression models (Fox & Monette, 1992; Zahan & Feng, 2020). After assessing collinearity, the remaining candidate variables were further selected using the stepwise regression technique, with entry and removal probabilities set at 0.05. The MLRM was thus fitted using the final set of covariates. The Likelihood Ratio Test (LRT) was used to evaluate whether the inclusion of predictors significantly improved the model fit relative to the null model. The Receiver Operating Characteristic (ROC) curve was obtained to examine the predictive power of the model. The Hosmer-Lemeshow goodness-of-fit test was used to examine the fitness of the model. Moreover, a scatter plot of H-L $\triangle\chi^2$ against the estimated probability, with symbol size proportional to $\Delta\beta$ was used to visually assess the agreement between predicted probabilities and observed outcomes. In addition, leverage versus Pearson residual plot was used to identify influential observations.

Multivariable logistic regression model

The outcome variable of our study is the survival status of under-five children (alive or dead). For the binary outcome variable, the most commonly used method is the logistic regression analysis. The logistic regression models are used to study the effects of predictor variables on binary outcomes. In the logistic regression model, suppose a sample of n independent observations of the pair (x_i,y_i), i = 1, 2, …., n. Where y_i is the status of newborn death before the age of five for the i^{th} child, and it is a value of the binary outcome variable. x_i's are the set of covariates and n is the total number of under-five children. If the status of under-five mortality follows a Bernoulli distribution with $\pi(x_i)$ as probability of under-five mortality, then its probability mass function can be expressed as (Hosmer, et al., 2013).

$$f(y_i/x) = \pi(x_i)^{y_i}(1-\pi(x_i))^{1-y_i},\ y_i = 0, 1;\ 0 \le \pi(x_i) \le 1;\ i = 1, 2, ..., n \qquad (1)$$

In this model, the proportion of under-five mortality is modeled in relation to explanatory variables. The curve to describe the above relationship is said to be S-shaped or sigmoid curve and may be explained in the functional form by logistic distribution given below.

$$\pi(x_i) = \frac{1}{1+e^{-z}} = \frac{e^z}{1+e^z} \quad , -\infty < z < \infty \qquad (2)$$

where z is the explanatory variable and it may be replaced by any linear combination of p covariates (i.e. $z = X_i' = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots + \beta_p x_p$). Then,

$$\pi(x_i) = \frac{1}{1+e^{-X_i'\beta}} = \frac{e^{X_i'\beta}}{1+e^{X_i'\beta}}$$

$$\Rightarrow \frac{\pi(x_i)}{1-\pi(x_i)} = \exp^{X_i'\beta}$$

$$\Rightarrow \ln\left(\frac{\pi(x_i)}{1-\pi(x_i)}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots + \beta_p x_p \qquad (3)$$

where the term $\pi(x_i)/1-\pi(x_i)$ is called the odds of occurrence of under-five death in relation to particular covariates. $\pi(x_i) = Pr(y_i=1/x_i)$ is the conditional probability of under-five death for a considered set of covariates. Additionally, $\beta_0$is the intercept and β_i's are the corresponding coefficients of x_i's.

RESULTS

Sociodemographic and other circumstances of study participants

A total sample of 205 mothers who had given live birth during the five years preceding the data collection was included in the study. A majority (84.87%) of the mothers were followers of the Hindu religion, Brahmin and Chhetri (Hill and Terai) were 39.02% followed by 23.90% Janajati (Newar, Hill and Terai Janajati). About 58.53% of mothers had a secondary or higher education,

and 11.70% were uneducated. Approximately 30% mothers had 3 or more CEB, 7.31% mothers were below 20 years at the time of childbirth, while 24.39% were 30 years or more. About 28% participants were from rural areas, 80.97% were housewives, and 13.65% fathers were uneducated. Nearly 47% of the respondents were from households that used piped/bottled/jar drinking water, 97.07% households had water access within premises, and about 12% participants were from households with no toilet facility. Concerning the type of cooking fuel, about 36% respondents used wood to cook food, and 16.09% respondents needed to travel more than 30 minutes to reach the nearest healthcare facility. The majority of the respondents received only one TT vaccine during pregnancy, 8.29% gave birth at home, and 20% deliveries were by caesarean section. About 17% children did not receive colostrum, and 28.29% of respondents exclusively breastfed for less than 6 months. Nearly 6% children born were unhealthy at the time of birth, about 17% respondents had pre- or post-term deliveries, and 6.29% were nonusers of contraceptives.

Table 1. Sample characteristics by survival status of under-five children across different levels of covariates.

Variables	Living status of the child		Total	OR (95% CI)
	Alive n (%)	Dead n (%)	n (%)	
	157 (76.59)	48 (23.41)	205 (100)	
Religion				
Hindu	140 (80.46)	34 (19.54)	174 (100)	1
Others	17 (54.84)	14 (45.16)	31 (100)	3.39 (1.52 - 7.55)*
Ethnicity				
Brahmin & Chhetri (Hill and Terai)	73 (91.25)	7 (8.75)	80 (100)	1
Other Terai caste	8 (50.00)	8 (50.00)	16 (100)	10.42 (2.98 - 36.38)*
Dalit (Hill & Terai)	19 (63.33)	11 (36.67)	30 (100)	6.03 (2.06 - 17.66)*
Janajati (Newar, Hill, and Terai Janajati)	44 (89.80)	5 (10.20)	49 (100)	1.18 (0.35 - 3.96)
Muslim	11 (50.00)	11 (50.00)	22 (100)	10.42 (3.33 - 32.61)*
Others	2 (25.00)	6 (75.00)	8 (100)	31.28 (5.28 - 185.20)*
Highest educational level of mother				
Secondary and higher	109 (90.83)	11 (9.17)	120 (100)	1
Basic	40 (65.57)	21 (34.43)	61 (100)	5.20 (2.30 - 11.74)*
No education	8 (33.33)	16 (66.67)	24 (100)	19.81 (6.92 - 56.69)*
Total children ever born (CEB)				
Less than 3	122 (84.14)	23 (15.86)	145 (100)	1
3 or more	35 (58.33)	25 (41.67)	60 (100)	3.78 (1.92 - 7.47)*
Mother's age at childbirth				
Below 20	11 (73.33)	4 (26.67)	15 (100)	1
20-25	57 (74.03)	20 (25.97)	77 (100)	0.96 (0.27 - 3.37)

25-30	52 (82.54)	11 (17.46)	63 (100)	0.58 (0.15 - 2.16)
30 or more	37 (74.00)	13 (26.00)	50 (100)	0.96 (0.26 - 3.57)
Place of residence				
Urban	132 (89.80)	15 (10.20)	147 (100)	1
Rural	25 (43.10)	33 (56.90)	58 (100)	11.61 (5.51 - 24.47)*
Mother's occupation				
Did work	37 (94.87)	2 (5.13)	39 (100)	1
Did not work (housewife)	120 (72.29)	46 (27.71)	166 (100)	7.09 (1.64 - 30.62)*
Highest education level of father				
Secondary and higher	109 (90.83)	11 (9.17)	120 (100)	1
Basic	31 (54.39)	26 (45.61)	57 (100)	8.31 (3.69 - 18.68)*
No education	17 (60.71)	11 (39.29)	28 (100)	6.41 (2.40 - 17.07)*
Father's occupation				
Others (technical/managerial, etc.)	104 (88.89)	13 (11.11)	117 (100)	1
Agriculture (self-employed)	10 (52.63)	9 (47.37)	19 (100)	7.2 (2.47 - 20.97)*
Unskilled	20 (60.61)	13 (39.39)	33 (100)	5.2 (2.10 - 12.86)*
Foreign employment	22 (66.67)	11 (33.33)	33 (100)	4 (1.58 - 10.09)*
Source of drinking water				
Piped/Bottle/Jar	82 (85.42)	14 (14.58)	96 (100)	1
Tubewell	75 (68.81)	34 (31.19)	109 (100)	2.65 (1.32 - 5.32)*
Time to get water source				
On premises	155 (77.89)	44 (22.11)	199 (100)	1
Outside premises	2 (33.33)	4 (66.67)	6 (100)	7.04 (1.24 - 39.74)*
Toilet facility				
With facility (any type)	144 (79.56)	37 (20.44)	181 (100)	1
No facility/bush/field	13 (54.17)	11 (45.83)	24 (100)	3.29 (1.36 - 7.94)*
Type of house				
Finished	99 (95.19)	5 (4.81)	104 (100)	1
Others (& partially finished)	58 (57.43)	43 (42.57)	101 (100)	14.67 (5.50 - 39.15)*
Family size				
4 or less	71 (81.61)	16 (18.39)	87 (100)	1
More than 4	86 (72.88)	32 (27.12)	118 (100)	1.65 (0.83 - 3.25)
No. of children age 5 or below in the house				
Less than 2 (0 and 1)	124 (77.99)	35 (22.01)	159 (100)	1
2 or more (2 to 5)	33 (71.74)	13 (28.26)	46 (100)	1.39 (0.66 - 2.93)
Sex of household head				
Male	117 (76.47)	36 (23.53)	153 (100)	1
Female	40 (76.92)	12 (23.08)	52 (100)	0.97 (0.46 - 2.05)
Type of cooking fuel				

LPG	124 (93.94)	8 (6.06)	132 (100)	1
Wood	33 (45.21)	40 (54.79)	73 (100)	18.78 (8.02 - 43.98)*
Travel time to nearest healthcare facility (in min.)				
30 or less	144 (83.72)	28 (16.28)	172 (100)	1
More than 30	13 (39.39)	20 (60.61)	33 (100)	7.91 (3.52 - 17.73)*
Birth order number				
First	62 (83.78)	12 (16.22)	74 (100)	1
Second	61 (81.33)	14 (18.67)	75 (100)	1.18 (0.50 - 2.76)
Third	27 (71.05)	11 (28.95)	38 (100)	2.10 (0.82 - 5.35)
4th or above	7 (38.89)	11 (61.11)	18 (100)	8.11 (2.61 - 25.16)*
Type of birth				
Single	153 (76.88)	46 (23.12)	199 (100)	1
Multiple	4 (66.67)	2 (33.33)	6 (100)	1.66 (0.29 - 9.37)
Preceding birth interval in months				
24 or more	92 (76.67)	28 (23.33)	120 (100)	1
Less than 24	3 (27.27)	8 (72.73)	11 (100)	8.76 (2.17 - 35.27)*
Size of child at birth				
Average	126 (86.30)	20 (13.70)	146 (100)	1
Smaller or Larger than average	27 (54.00)	23 (46.00)	50 (100)	5.36 (2.58 - 11.12)*
Sex of child				
Male	80 (75.47)	26 (24.53)	106 (100)	1
Female	77 (77.78)	22 (22.22)	99 (100)	0.87 (0.45 - 1.68)
No. of TT injections received before childbirth				
2 or more	77 (84.62)	14 (15.38)	91 (100)	1
Less than 2	80 (70.18)	34 (29.82)	114 (100)	2.33 (1.16 - 4.69)*
Delivery assistance				
Health professionals	147 (79.03)	39 (20.97)	186 (100)	1
Others (FCHVs, relatives, friends, neighbors)	10 (52.63)	9 (47.37)	19 (100)	3.39 (1.28 - 8.92)*
Number of antenatal care visits				
4 or more	145 (76.72)	44 (23.28)	189 (100)	1
Less than 4	12 (75.00)	4 (25.00)	16 (100)	1.09 (0.33 - 3.57)
Place of delivery				
Health centers	148 (78.72)	40 (21.28)	188 (100)	1
Home	9 (52.94)	8 (47.06)	17 (100)	3.28 (1.19 - 9.06)*
Mode of delivery				
Normal	119 (72.56)	45 (27.44)	164 (100)	1
Caesarean	38 (92.68)	3 (7.32)	41 (100)	0.20 (0.06 - 0.71)*
Child received colostrum				
Yes	139 (81.76)	31 (18.24)	170 (100)	1

No	18 (51.43)	17 (48.57)	35 (100)	4.23 (1.96 - 9.13)*
Duration of breastfeeding (in months)				
6 or more	138 (93.88)	9 (6.12)	147 (100)	1
Less than 6	19 (32.76)	39 (67.24)	58 (100)	31.47 (13.19 - 75.05)*
Gestational age of child				
Term	134 (78.82)	36 (21.18)	170 (100)	1
Pre-term	16 (66.67)	8 (33.33)	24 (100)	1.86 (0.73 - 4.69)
Post-term	7 (63.64)	4 (36.36)	11 (100)	2.12 (0.58 - 7.66)
Health status of child at the time of birth				
Healthy	154 (79.79)	39 (20.21)	193 (100)	1
Unhealthy	3 (25.00)	9 (75.00)	12 (100)	11.84 (3.06 - 45.83)*
Use of contraceptives				
Users of modern methods	63 (82.89)	13 (17.11)	76 (100)	1
Nonusers	94 (72.87)	35 (27.13)	129 (100)	1.80 (0.88 - 3.67)
Previous death of child				
No	144 (77.01)	43 (22.99)	187 (100)	1
Yes	13 (72.22)	5 (27.78)	18 (100)	1.28 (0.43 - 3.81)

Factors affecting U5M in study areas

The results of bivariate analysis, which consist of unadjusted ORs and their 95% CIs are shown in the last column of Table 1. The Wald z-test was used to examine the significance of each covariate with the outcome variable. Considering the 0.05 significance level, out of 34 covariates included in the analysis, 24 were found statistically significant. These were the candidate variables for multivariate analysis. However, preceding birth interval, one of the significant variables in bivariate analysis, was eliminated from the analysis due to a large number of missing values, because it is not applicable for firstborn children. To assess the multicollinearity among these covariates, GVIFs were calculated. The covariates religion, CEB, place of residence, mother's occupation, source of drinking water, time to get water source, toilet facility, travel time to nearest healthcare facility, delivery assistance, place of delivery, child received colostrum, and duration of breastfeeding had GVIFs of 1.58 or more; hence, these covariates were therefore excluded from subsequent analysis. To further screen the covariates for MLRM, both forward and backward stepwise regression were performed. Both methods provided the six covariates as candidate variables for the final model at the 0.05 level of significance.

Table 2 shows the outcomes of multivariate analysis after controlling for all factors. The ethnicity of the mother appeared as one of the influential factors for the survival of under-five children. Muslim mothers experienced 10.21 times higher risk of U5M (AOR = 10.21, 95% CI: 1.42 – 73.30) than Brahmin and Chhetri mothers. The health status of the child at the time of birth appeared as an influencing factor of U5M. Those children who were born unhealthy at the time of birth faced 19.25 times greater odds of dying before the age of five compared to healthy children (AOR = 19.25, 95% CI: 2.00 – 185.04).

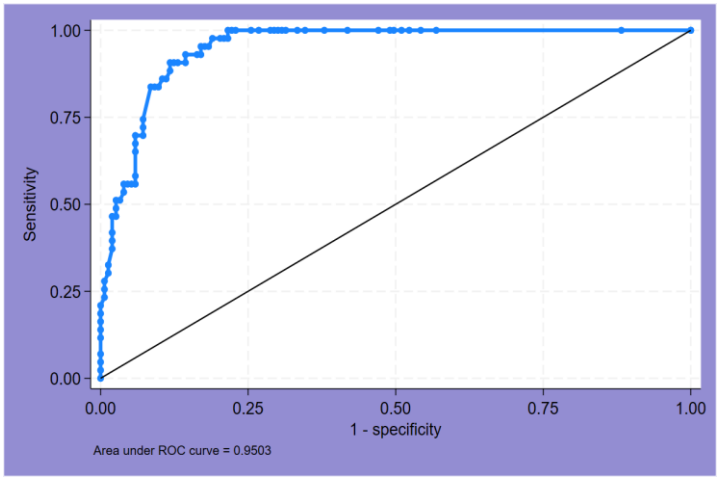
Table 2. Result of the MLRM for the survival status of under-five children.

Explanatory variables	AOR	p-value	95% CI
Ethnicity			
Brahmin & Chhetri (Hill and Terai)	1		
Other Terai caste	5.46	0.095	0.74 - 40.06
Dalit (Hill & Terai)	3.54	0.161	0.60 - 20.86
Janajati	0.49	0.436	0.08 - 2.89
Muslim	10.21	0.021	1.42 - 73.30
Others	7.28	0.146	0.50 - 106.20
Health status of child at the time of birth			
Healthy	1		
Unhealthy	19.25	0.01	2.00 - 185.04
Highest education level of mother			
Secondary and higher	1		
Basic	3.31	0.111	0.76 - 14.45
No education	14.59	0.016	1.65 - 128.88
Size of child at birth			
Average	1		
Smaller or larger than average	3.49	0.046	1.02 - 12.00
Highest education level of father			
Secondary and higher	1		
Basic	2.49	0.236	0.54 - 11.38
No education	0.048	0.009	0.004 - 0.47
Type of cooling fuel			
LPG	1		
Wood	32.20	< 0.001	7.78 - 133.22

The highest education level of mothers remained statistically significant. The children of uneducated mothers were 14.59 times more likely to die before the age of five (AOR = 14.59, 95% CI: 1.65 – 128.88) compared to those whose mothers had secondary and higher levels of educational achievement. Similarly, the size/weight of child at birth obtained as another important covariate associated with U5M. Infants who were smaller or larger than average in size at birth had 3.49 times higher risk of U5M (AOR = 3.49, 95% CI: 1.02 – 12.00) in contrast to those who were average in size. Contrary to common expectation, children whose fathers had no education were about 92% less likely to experience U5M compared to those whose father had secondary and higher education (AOR = 0.048, 95% CI: 0.004 – 0.47). It is also found that the households using wood as cooking fuel experienced a higher chance of U5M. Children living in households that used wood as the primary source of cooking fuel had 32.20 times higher odds of U5M compared to those in households that used LPG (AOR = 32.20, 95% CI: 7.78 – 133.22). The high ORs and wide 95% CIs for AOR observed in this study might be due to the issue of small sample size.

Model fit and predictive performance of the model

The LRT value with 12 degrees of freedom, used to assess whether the predictors in the fitted MLRM significantly improve the fit over the null model, was obtained as 114.18 with a p-value of less than 0.001. The significant result of the test statistic indicates that the predictors in the fitted model explain the survival status of under-five children substantially better than the null model. The McFadden pseudo-R^2 of 0.5536 indicates that the model fits the data well and provides a significant improvement over a model with no predictors. Likewise, the Hosmer-Lemeshow goodness-of-fit test provided a chi-square test statistic of 4.35 at 6 degrees of freedom and a p-value of 0.6301. Here, in contrast to the usual ten quantile groups, only eight distinct quantiles were formed because of ties while analyzing the data. These test results demonstrate that the predicted probabilities from the model align with the observed outcomes. The predictive performance of the fitted MLRM was assessed using the ROC curve, as shown in Figure 2. The area under the curve (AUC) was 0.9503, indicating an excellent discriminatory ability between cases and non-cases of the outcome variable. The sensitivity computed for the model suggests that it correctly identified 69.77% of under-five deaths, while the specificity of the model implies that it correctly classified 92.81% of surviving children. Overall, the model correctly classified 87.76% of all observations.



Sensitivity = 69.77% Specificity = 92.81%

Fig. 2. Receiver operating characteristics (ROC) curve of MLRM for predicting the U5M.

Plot of H-L dx^2 $(\Delta\chi^2)$ against the estimated probability

Figure 3 shows a scatter diagram between H-L $\triangle\chi^2$ and estimated probability with symbol size proportional to $\Delta\beta$ based on the fitted model. It helps to visually assess how closely the predicted probabilities of an event align with the observed outcomes. The H-L test divides the observed events and the predicted probabilities generally into ten deciles and computes the test

statistics. Here, most deciles have $\triangle\chi^2$ values close to zero, indicating good agreement between observed and predicted outcomes, which is reasonably satisfied. The larger bubbles close to zero suggest that groups with many observations are well-fitted.

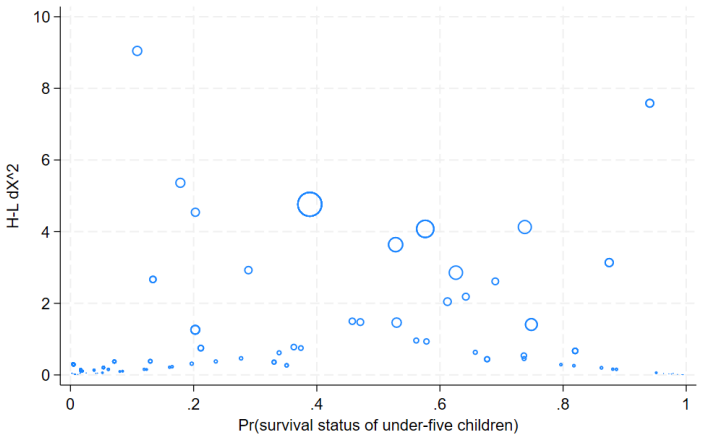


Fig. 3. Plot of H-L dx^2 ($\triangle\chi^2$) against the estimated probability with symbol size proportional to $\Delta\beta$

Plot of leverage versus Pearson residual

Figure 4 is used to identify influential observations or outliers in the data. Almost all points are within the ± 2 Pearson residual band, indicating that the predicted probabilities are closely distributed with observed outcomes for most of the cases. However, only a few observations are beyond this limit, which do not have a considerable effect on the model's adequacy.

Model specification

Table 3 illustrates the coefficients and p-values of the model considering the original outcome variable and the model's predicted value ($\hat{y}$) and the square of the predicted value ($\hat{y}^2$) as independent variables. The model assesses the appropriateness of the functional form of the model and identifies whether important covariates are missing. The significant result of the coefficient $\hat{y}$ and the non-significant coefficient of $\hat{y}^2$indicates that the model is correctly specified.

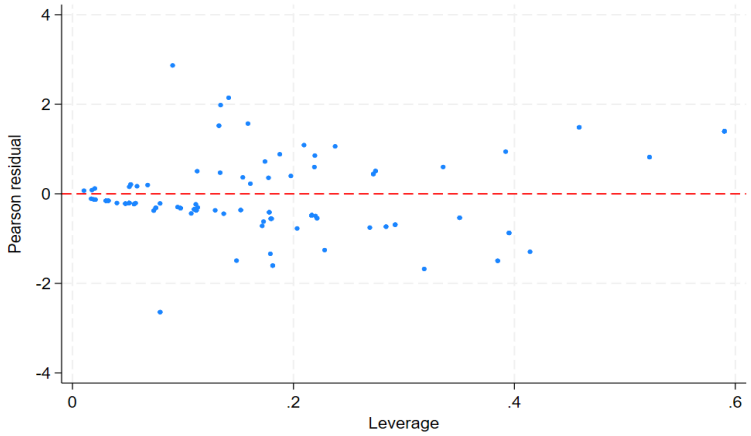


Fig. 4. Leverage vs. Pearson residual plot

Table 3. Predicted value and the square of the predicted value of the model.

	coefficient	p-value
$\hat{y}$	0.9318	< 0.001
$\hat{y}^2$	-0.0961	0.118
Constant	0.222	0.468

DISCUSSION

In this study, we identified some important factors related to U5M in the selected regions, considering various potential variables from the literature. This research obtained information on 205 live-born children during the five years before the survey. Although different strategies and efforts have been made to reduce U5M, many factors continue to play a crucial role in the survival of under-five children. The MLRM was fitted to identify the significant factors associated with U5M. The study found that the ethnicity of mothers, health status of children at the time of birth, education level of mothers, size of child at birth, education level of father, and type of cooking fuel were the key factors associated with U5M in the study areas.

Our study shows a significant ethnic disparity in U5M, consistent with previous studies (Victora, et al., 2020; Adedini, et al., 2015). Children born to mothers from the Muslim community experienced a higher risk of U5M than those of Brahmin and Chhetri mothers. Such variations may reflect inequalities in socioeconomic conditions, access to healthcare services, and cultural practices. Continuous assessment of ethnic differences is essential for monitoring trends and evaluating targeting interventions aimed at reducing U5M. Future research is needed to understand

the factors causing ethnic variations in child mortality. The health status of the child at the time of birth emerged as a significant factor of U5M. Children who were born unhealthy were more likely to die before reaching the age of five than those who were born healthy, in line with findings reported by the World Health Organization (WHO). Not only at the local or regional level, but premature births, birth complications, neonatal infections, and congenital anomalies are the leading causes of neonatal deaths all over the world (World Health Organization [WHO], 2024). The unhealthy birth conditions, such as low birth weight, prematurity, birth defects/complications, increase U5M by weakening the child's immunity and psychological stability. These newborns are more susceptible to infections, respiratory problems, and early neonatal complications, which substantially elevate their risk of dying before age five (Institute of Medicine of the National Academies, 2003). Mother's education was one of the important protective factors of U5M in this study. Children whose mothers were uneducated experienced a higher risk of mortality before the age of five than children whose mothers had a secondary or higher level of education. Such a finding of the key role of maternal education in reducing U5M is consistent with many studies conducted in different regions (Fenta & Fenta, 2020; Ezeh, et al., 2015; Iddrisu, et al., 2020; Yaya, et al., 2018; Ogbo et al., 2019; Ghimire et al., 2019). Obviously, a mother's education has a positive impact on the survival of under-five children. Educated mothers have a good understanding of the overall well-being of children, encompassing healthcare knowledge, utilization of maternal and child health services, nutrition, breastfeeding, sanitation and hygiene, family planning, and reproductive health, among other aspects. Such knowledge helps in reducing childhood mortality. However, father's education was not found to be protective against U5M in the multivariate analysis. This may be due to the low statistical power induced from small sample, which could have produced unstable estimates. The size of the child at birth is another important risk factor associated with U5M, which is similar to the findings of previous studies (Jana, et al., 2023; Ogbo, et al., 2019). Children with birth weights smaller or higher than average faced a higher odds of U5M compared to those of average birth weight. This finding highlights the need for a balanced maternal diet for a healthy and normal birth weight. The next significant covariate of U5M is the type of cooking fuel. Children who live in households where wood is the primary source of cooking fuel experienced a greater risk of U5M than those in households that use LPG to cook food. This finding is also in line with the existing studies (Kaulu, et al., 2025; Basu, et al., 2024). This observation is associated with the socioeconomic status of the households. As per the concepts of socioeconomic determinants of health outcomes, poorer households that cannot afford cleaner processed fuels are more likely to experience U5M than richer households.

Limitations of the study

This study has some limitations. It consists reasonably small sample, so the results of the multivariable logistic regression may provide unstable coefficients and wider confidence intervals. The covariates with a small sample among the number of cases in the outcome variable might not examine the significant associations, even though they are important variables. Likewise, the findings of this study mainly represent the study areas rather than the broader population. The information in this study was gathered from respondents' self-reports, which could lead to potential recall bias,

particularly over an extended period. Moreover, the contextual and qualitative factors that could affect U5M were not included in the study. The assessment of the cause-and-effect relationship was also restricted in the analysis due to the cross-sectional study design used in the study.

CONCLUSION

The study concludes that the children of Muslim mothers, children of those mothers who have no education, households that use wood to cook food, and an unhealthy child at the time of birth experienced a significantly higher risk of U5M. Ensuring at least secondary education for women and promoting adult literacy and health literacy targeting uneducated women, educating the community about the adverse effects of indoor air pollution, and promoting the use of appropriate ventilation, clean stoves, LPG, or electricity, etc. are crucial for reducing U5M. Likewise, strengthening antenatal care to detect and manage safe and healthy pregnancy, expanding the coverage of skilled birth attendance and essential newborn care facilities, and improving the referral system for high-risk pregnancies and critical newborns should be of high priority to curtail U5M in the study areas.

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CONFLICT OF INTEREST

The authors have declared that there is no competing interest.

AUTHOR CONTRIBUTION

MKB conceptualized the study, conducted the literature review, carried out the methodology, prepared the questionnaire, collected and managed the data, performed the statistical analysis, interpreted the findings, and drafted the manuscript. SPK contributed to the review process, edited the manuscript, monitored, and supervised the overall study. Both authors examined and approved the final version of the manuscript.

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ETHICAL STATEMENT

Ethical approval for this research was obtained from the Institutional Review Committee of the Institute of Science and Technology, Tribhuvan University, Nepal (Ref. No.: 102/079/080).

The study strictly followed the national ethical guidelines published by the Nepal Health Research Council during the study.

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