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Factors Influencing Under-Five Mortality in India: A Survival Analysis Approach

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KEYWORDS

Survival, Child mortality, Risk, Kaplan-Meier, Cox Proportional hazard.

ABSTRACT: Infant and child mortality remains a major public health concern in developing countries such as India, where socioeconomic and demographic disparities substantially influence health outcomes. This study examines the determinants of under-five mortality using data from the National Family Health Survey (NFHS). Survival patterns were analyzed using Kaplan–Meier survival curves and associated risk factors were quantified using the Cox proportional hazard model. The results indicate that size at birth, mother's education, household wealth, and birth order are the most influential determinants of child survival. Children born small experienced substantially higher mortality risk, while higher maternal education and improved household wealth were associated with significantly better survival outcomes. Second and third-born children exhibited lower mortality risks compared to first born and higher order births. Additionally, children who resided in urban areas showed better survival prospects than those in rural areas. These findings highlight the combined influence of biological vulnerability at birth and socioeconomic disadvantage on under-five mortality. Policies aimed at improving maternal nutrition, expanding women's education, reducing poverty, and strengthening healthcare access particularly in rural areas are essential for reducing child mortality and achieving equitable child health outcomes in India.

1. Introduction

Infant and child mortality remains a significant public health concern, particularly in developing countries such as India, where socioeconomic and demographic disparities can deeply affect health outcomes. Understanding the factors that contribute to infant and child mortality is crucial to shaping effective health policies and interventions. The National Family Health Survey (NFHS) provides extensive data on a variety of health indicators, offering a rich resource for analyzing mortality trends and associated risk factors in the Indian context.

In 2023, WHO reported that almost five million children under the age of five died worldwide. In every population, determinants such as maternal health programs, duration of breastfeeding, mother's education, mother's age, birth order, place of residence, size at birth are critical in reducing infants and child mortality. Mosley & Chen (1984) developed a framework for the analysis of determinants, which was the combined form of medical and social factors. In recent years, numerous studies have also been acknowledged for analyzing the survival benefits of socioeconomic, demographic, and environmental factors of children.

Numerous studies have examined the impact of educated mothers on the health of their children. Because educated women are better able to handle the modern world, they can talk to doctors more easily and benefit from various policies and treatments for their children. Different national educational systems may influence children's health in different ways, Caldwell (1979). Mothers with lower levels of education have higher infant mortality rates than mothers with higher levels of education (Murphy & Wang, 2001).

According to Masuy-Stroobant (2002), a newborn is regarded to be in the neonatal phase if they are 28 days old. The risk of infant mortality during this time is significant because of serious infections (26%), asphyxia (23%), and preterm births (28%). Armstrong (2002) evaluated the impact of the household environment, socioeconomic status, and demographic health-seeking behavior on baby and child survival in Tanzania.Wang (2003) conducted research on the survival of children in Ethiopia throughout three time periods: neonatal,

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newborn, and under-five years. The study considered the mother's educational background, location (rural, urban), religious affiliation, income status, and access to basic environmental services.

Urban/rural disparities are more significant than many other social and economic traits. Numerous investigations have shown a negative correlation between maternal education level and child mortality (Pandey et al. (1998); Kravdal (2004)). Koenig (1992) and Khasakhala (2003) contend that maternal education is merely a sign of socioeconomic variables that have a direct impact on infant mortality.White (2006) conducted an analysis using data from Andhra Pradesh, India, to examine the effects of biological variables on infant mortality, including tetanus injection, prenatal care, and birth order. Singh et al. (2007) found that the impact of breastfeeding and a few other socioeconomic and demographic factors significantly affect infant death in India.

The effect of a mother's age on child mortality is a topic of great interest to researchers, and numerous studies have found a curvilinear link between a mother's age and newborn death. There is a significant risk of child death if a mother gives birth while still a teenager (Maitra, 2004; Geronimus, 1986). Muluye & Wencheko (2012) explained that infant mortality in Ethiopia is influenced by demographic, socioeconomic, and environmental factors. Based on a comparative analysis, Chowdhury (2013) discovered that in Bangladesh, proximal factors had a greater impact on infant mortality than socioeconomic factors. Sirohi & Rai (2019) analyzed infant mortality determinants using Kaplan-Meier and Cox models on NFHS 2005-06 data, highlighting maternal health, socioeconomic factors, breastfeeding, education, and policy impacts in India. This research aims to identify important risk factors for under-five mortality in India utilizing existing data and statistical methodologies. The main determinants of under-five mortality, according to the hypothesis of the study, are mother's education, caste, wealth index, and type of residence, child's sex, birth order, and size of child at birth, mother's age at birth size. The study examines risk variables related to children under the age of five.

2. Data and Methodology

Data are taken from the National Family Health Survey, which was conducted between 2019 and 21. The 2019–20 National Family Health Survey (NFHS–5), the fifth in the NFHS series, provides information on the population, health, and nutrition of each state and union territory in India. Under the direction of the Ministry of Health and Family Welfare (MoHFW), Government of India, all five NFHS surveys were carried out. For all surveys, MoHFW chose the International Institute for Population Sciences (IIPS), located in Mumbai, as the focal agency.

According to the National Family Health Survey (NFHS-5), the under-five mortality rate (U5MR) in India is 42 per 1,000 live births. A total of 232920 children under the age of five were evaluated and analyzed. Kaplan-Meier estimator and Cox proportional hazard model are used to analyze the data. In this study, the primary explanatory factors are the mother's education (no education, primary, secondary, and higher education), caste (SC, ST, OBC, GEN); wealth index (poor, middle, rich), and type of residence (urban and rural), child's sex (male, female), birth order (1, 2, 3, and 4 or more), and size of child at birth (large, average, small), mother's age (17-20 years, 21-24 years, 25-28 years,29-32 years, 33-36 years, 36+ years).

Table 1: Descriptive Statistics of under-five children in India (N = 232920)

Covariates	Category	Censored	Dead	Total
Sex	Female	108393	3862	112255
	Male	115825	4840	120665
Place of Residence	Rural	178334	7387	185721
	Urban	45884	1315	47119
Mother's Age (Years)	17-20	90715	3906	94621
	21-24	81704	2981	84685
	25-28	29038	923	29961
	29-32	8528	259	8787
	33-36	1837	63	1900
	36+	847	44	891
Mother's Education	No Education	48527	2683	51210
	Primary	28729	1352	30081
	Secondary	115857	4007	119864
	Higher	31105	660	31765
Birth Order	1	85828	3311	89139
	2	74171	2348	76519
	3	35082	1433	36515
	4 or more	29137	1610	30747
Child size at Birth	Large	40533	1421	41954
	Average	158816	5113	163929
	Small	21939	1553	23492
	Unknown	2930	615	3545
Wealth Index	Poor	112406	5463	117869
	Middle	42592	1491	44083
	Rich	68220	1748	69968
Caste	SC	45723	2125	47848
	ST	45308	1810	47118
	OBC	85782	3311	89093
	General	35483	1090	36573

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Statistical Analysis

Cox proportional hazards regression is used to accomplish the study's goals. The analysis is performed using R software. The child's age (in months) is used as the time variable, and the child's alive/death status is used as the censoring variable in the Cox models.

The Cox proportional hazards model can be expressed as:

$$h(t|x) = h_0(t)exp\left(\sum_{i=1}^{p}\beta_i x_i\right) \quad (1)$$

In (1), $h(t|x)$ is the hazard function at time t for the i -th individual, $\beta_1, \beta_2, \ldots . \beta_p$ are the regression coefficients for the explanatory variables, is a vector of regression coefficient, and $h_0(t)$ is the baseline hazard function. The proportional form of the Cox model can be obtained by dividing Equation (1) by the baseline hazard h_0(t), yielding:

$$\frac{h(t|x)}{h_0(t)} = exp\left(\sum_{i=1}^{p}\beta_i x_i\right) \quad (2)$$

Taking the logarithm of Equation (2) gives:

$$ln\left(\frac{h(t|x)}{h_0(t)}\right) = \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p \quad (3)$$

Equation (3) shows that for each value of t, the hazard function of the i-th individual is proportional to the baseline hazard function.

The Kaplan-Meier estimator is a non-parametric method used to estimate the survival function from censored data. For a given time t, the survival function S(t) is estimated as:

$$S(t) = \prod_{t_i \le t}\left(1 - \frac{d_i}{n_i}\right)$$

where:

- t_i : Time points where events occur.
- d_i : Number of events (e.g. deaths or failures) at t_i.
- n_i : Number of individuals at risk just before t_i.

3. Results

From the dataset of 232920 responses, a total of 8,702 deaths of children under five years of age were recorded. Both Kaplan–Meier survival curves and the Cox proportional hazards model were used to examine the factors associated with child mortality. The Kaplan–Meier curves provide a clear visual representation of survival differences across groups as shown in figure 1, figure 2, figure 3 and figure 4, while the Cox model quantifies relative risks (represented in table 2). Among the variables studied, education of mother, the size of the child at birth, the order of birth and the wealth index emerged as the most influential. The Cox proportional hazards model indicated that children born small experienced a substantially higher risk of mortality, with a hazard ratio of 1.99, implying nearly double the hazard compared with children born of average or large size. Consistent with this finding, the Kaplan–Meier analysis showed that ap- proximately 26% of small-sized children died before reaching five years of age. Birth order also demonstrated a significant association with child survival as Kaplan–Meier curves indicated higher survival probabilities among second and third-born children, whereas first-born and higher-order (fourth or above) children experienced comparatively lower survival.

The Cox estimates further indicated that second-and third-born children had 22% (HR=0.787) and 11% (HR=0.9) lower risks of mortality, whereas children of fourth or higher orders again faced greater risks. Similarly, wealth-based inequalities were visible in the Kaplan–Meier curves and supported by Cox model results, as children from rich and middle-income households had 30% (HR=0.699) and 19% (HR=0.815) lower risks of mortality than those from poor households. Other covariates also played a role. The cox model showed that children from SC and OBC social groups has 28% (HR=1.284) and 14% (HR=1.146) lower risk as compared to children from General. Gender differences revealed that male children had poorer survival chances, with a 16% (HR=0.841) higher mortality risk compared to females. Rural–urban comparisons further showed that children from rural areas had lower survival probabilities and an 11% (HR=1.11) higher hazard of death than their urban counterparts.

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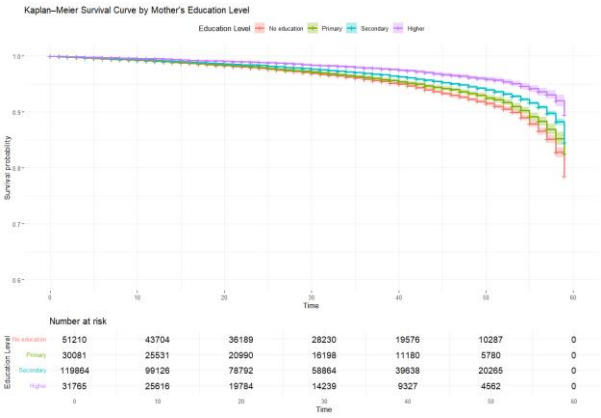

Figure 1: Kaplan-Meier Survival Curves by Mother's Education level.

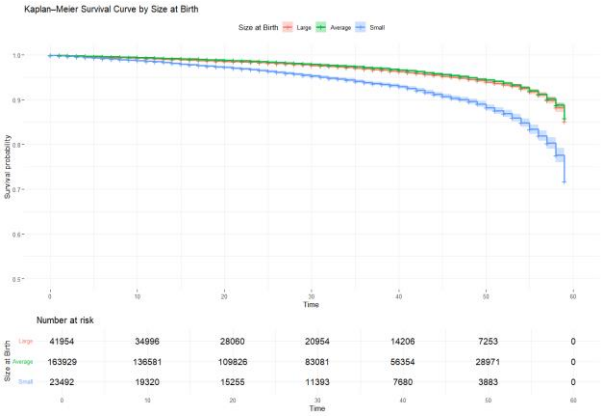

Figure 2: Kaplan-Meier Survival Curves by Size of child at birth.

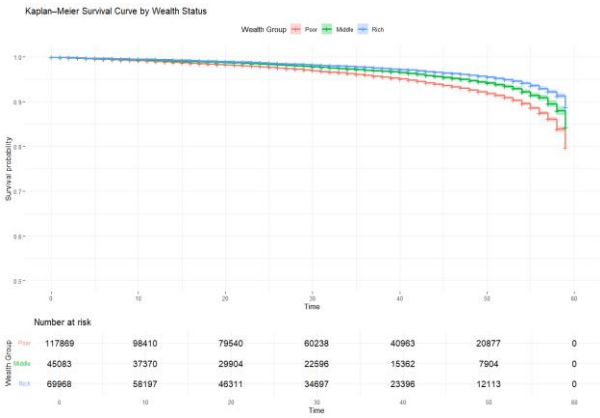

Figure 3: Kaplan-Meier Survival Curves by family Wealth Index.

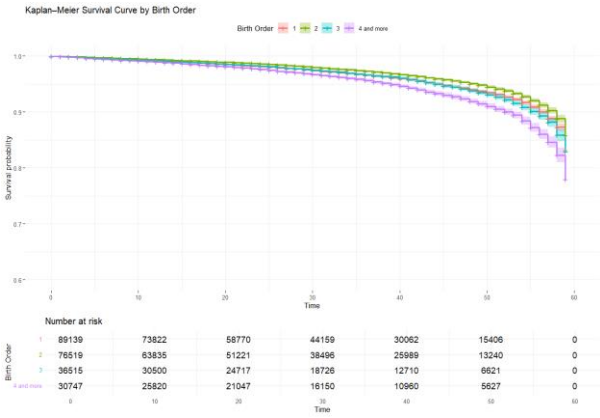

Figure 4: Kaplan-Meier Survival Curves by Birth order.

Table2: Cox Proportional Hazards Model results

Covariate	**HR**	**SE**	**Z**	**P-value**
Sex				
Male (ref.) Female	0.841	0.023	-7.495	< 0.001***
Size at birth				
Large (ref.) Average	0.914	0.032	-2.780	0.005**
Small	1.986	0.039	17.446	< 0.001***
Don't know	4.004	0.053	26.199	< 0.001***
Social Group (Caste)				

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General (ref.)				
SC	1.284	0.039	6.437	< 0.001***
ST	0.966	0.041	-0.851	0.395
OBC	1.146	0.036	3.778	< 0.001***
Place of Residence				
Urban (ref.)				
Rural	1.110	0.035	2.987	0.003**
Birth Order				
One (ref.)				
Two	0.787	0.029	-8.327	< 0.001***
Three	0.900	0.035	-3.050	0.002**
Four or more	1.047	0.036	1.286	0.198
Mother's Education				
No education (ref.)				
Primary	0.933	0.036	-1.907	0.057
Secondary	0.863	0.030	-4.950	< 0.001***
Higher	0.703	0.052	-6.807	< 0.001***
Wealth Index				
Poor (ref.)				
Middle	0.815	0.033	-6.288	< 0.001***
Rich	0.699	0.036	-10.029	< 0.001***
Mother's Age (years)				
17–20 (ref.)				
21–24	1.010	0.025	0.396	0.692
25–28	0.991	0.039	-0.225	0.822
29–32	0.986	0.067	-0.213	0.832
33–36	1.145	0.130	1.045	0.296
36+	1.508	0.156	2.638	0.008**
Anemia Status				
Severe (ref.)				
Mild	0.883	0.067	-1.852	0.064
Moderate	0.865	0.068	-2.140	0.032*
No anemia	0.803	0.067	-3.283	0.001**

Note: HR = Hazard Ratio; ref. = reference category. $^{<}0.001$, $^{**}p < 0.01$, $^{*}p < 0.05, p < 0.10$.

4. Discussion

The study provides comprehensive evidence on the determinants of child mortality in India by jointly applying Kaplan–Meier survival analysis and the Cox proportional hazards model. The concordance between these two approaches strengthens the robustness of the findings and highlights that under-five mortality is primarily driven by a combination of biological conditions at birth and household socioeconomic circumstances. Among the factors examined, size at birth, mother's education, household wealth, and birth order emerged as the most influential determinants of child survival.

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Size at birth was identified as the strongest predictor of under-five mortality. Children born small faced nearly double the risk of death compared with those born of average or large size (HR = 1.99). This elevated risk was also clearly reflected in the Kaplan–Meier survival curves, which showed that approximately 26% of small-sized children died before reaching five years of age. These findings underscore the critical importance of maternal health, nutritional status, and quality antenatal care during pregnancy. Poor fetal growth remains a major biological pathway through which early childhood mortality occurs, emphasizing the need for targeted interventions aimed at improving maternal nutrition and pregnancy monitoring.

Mother's education emerged as another key determinant of child survival. Children of educated mothers, particularly those with secondary or higher education, exhibited substantially lower mortality risks compared with children whose mothers had no formal education. Educated mothers are more likely to possess better knowledge of nutrition, hygiene, immunization, and timely healthcare utilization, which directly contributes to improved child health outcomes. These finding highlights women's education as a long-term and sustainable investment for reducing child mortality.

Strong wealth-related gradients in child survival were evident in both the Kaplan–Meier and Cox model results. Children from middle and rich-income households experienced 19% and 30% lower mortality risks, respectively, compared with children from poor households. These disparities reflect unequal access to essential resources such as adequate nutrition, clean water, sanitation, and quality healthcare services. Despite improvements in child health programs, poverty continues to be a fundamental determinant of under-five mortality, reinforcing the importance of socioeconomic development and targeted support for vulnerable households.

Birth order also played a significant role in shaping child survival. Second- and third-born children showed higher survival probabilities and significantly lower mortality risks than first-born children, while higher-order births (fourth or above) were again associated with increased risk. This pattern suggests that maternal experience may improve care practices for early subsequent births, whereas resource constraints and caregiving burdens in larger families may adversely affect child survival. These findings emphasize the role of family planning, birth spacing, and maternal support services in improving child health outcomes.

In addition to these primary determinants, other factors such as child sex, place of residence, and social group also influenced under-five mortality, though their effects were comparatively smaller. Male children exhibited poorer survival prospects than females, rural children faced higher mortality risks than their urban counterparts, and social group differences reflected persistent structural inequalities. While secondary in magnitude, these factors remain important and should be considered in the design of comprehensive child health policies.

In summary, this study demonstrates that under-five mortality in India is largely driven by early biological vulnerability and socioeconomic disadvantage, with size at birth, maternal education, household wealth, and birth order being the most critical determinants. Effective reduction of child mortality will require integrated strategies that improve maternal nutrition and antenatal care, expand access to education for women, alleviate household poverty, and promote optimal family planning practices. Addressing these key factors simultaneously, while also strengthening healthcare access in rural and disadvantaged populations, is essential for achieving sustained and equitable improvements in child survival.

Conflict of interests

The author declares no conflict of interest.

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