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Research paper

Application of cox proportional hazard model to study the influence of determinants on under five mortality in Odisha, India

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Abstract

This study investigates under-five mortality (U5M) dynamics in Odisha using National Family Health Survey (NFHS) data through five models incorporating socio-economic, environmental, demographic, nutritional, and media variables. Employing the Cox Proportional Hazard model facilitates time-to-event analysis, accommodating censored observations and handling multiple covariates. The model's assumption of proportional hazard ratios over time suits the study of U5M, a time-dependent event. Table 1 presents hazard ratios from NFHS-4 to NFHS-5, revealing evolving trends in U5M risk factors. Significant contributors include maternal education, with hazard ratios decreasing across education levels, indicating improved associations with U5M in NFHS-5. Rural areas exhibit consistently higher hazard ratios, while wealthier households show potential rises in U5M risk. Varied impacts on U5M risk emerge for birth-related factors. These findings underscore the changing landscape of U5M risk factors in Odisha, offering a foundation for evidence-based policymaking to address evolving socio-demographic dynamics impacting child survival in the region.

Keywords: *Under-Five Mortality; Multivariate Proportional Hazard Model; NFHS-4; NFHS-5.*

1. Introduction

Child mortality stands as a vital health gauge mirroring the overall well-being of a population, where the under-five mortality rate (U5MR) acts as a pivotal metric. The commitment to diminishing child mortality on a global scale is emphasized in the Sustainable Development Goals, particularly Goal 3, with the target of reaching a U5MR of at least 25 per 1,000 live births. Within this framework, regions and states wield significant influence in formulating and executing policies to tackle challenges related to child health.

Odisha, situated in India and designated as an Empowered Action Group State, has experienced notable advancements in health and nutrition outcomes over the past two decades. The focus on reducing neonatal mortality rates and improving overall child health aligns with the broader global agenda. The National Family Health Survey (NFHS) serves as a valuable tool for assessing and understanding the dynamics of child health in Odisha, providing insights into the progress made and areas that require targeted interventions.

This examination delves into the outcomes derived from applying Cox's Proportional Hazard model to NFHS data from rounds 4 and 5, with a specific emphasis on the notable impacts of independent variables on under-five mortality in Odisha. By investigating socio-economic, environmental, demographic, nutritional, and media-related aspects, the objective of this research is to untangle the complex network of determinants that shape child survival in the region. Grasping these factors is crucial for crafting policies and interventions grounded in evidence, aligning with the dynamic landscape of child health in Odisha.

2. Data and variables

2.1. Description of variables selected for analysis

The focal point of this study is the dependent variable, which is the age of index children at the end of the month. To calculate the age of deceased children, the difference between the date of birth and the date of death is computed. For surviving children, their age is determined by subtracting their date of birth from the interview date. In this retrospective survey, the age of children still alive during the interview is treated as censored, as predicting their future lifespan precisely is not possible. Using NFHS-5 data, the study imputes ages in completed months for both index children and those who have passed away (Months imputed at Death). For children who lived beyond fourteen days but eventually succumbed, their age is considered one month in this analysis.

2.2. Independent variables

This research undertakes a thorough analysis of independent variables categorized into five distinct groups. Firstly, within Socioeconomic Variables, vital determinants such as Mother's education, Wealth Index, Sex, Place of residence, region of residence, and Caste undergo scrutiny, revealing the complex interplay between social and economic dynamics. Secondly, the exploration extends to Environmental Contamination, examining aspects like Sources of drinking water, toilet facilities, housing construction material, and cooking fuel. Grasping the environmental context is crucial for assessing its potential influence on the subject under study.

Thirdly, the study considers Demographic Factors, incorporating variables like the Age of the mother at the time of birth, Birth order, and the number of children. These demographic markers contribute valuable insights into the population under scrutiny. Seeking Behavioral factors form the fourth category, encompassing variables such as place of delivery, current breastfeeding practices, contraceptive use, and birth weight. These parameters offer a nuanced perspective on health-related decisions and outcomes. Finally, Social Mass Media constitutes the fifth category, evaluating the influence of variables like watching television and covered health insurance. This highlights the role of media exposure in shaping health-related attitudes and behaviors. The comprehensive categorization of independent variables ensures a multifaceted analysis, facilitating a nuanced understanding of the study's subject matter.

2.3. Cox regression model

In this study, the analysis of survival data employed the Cox Proportional Hazard regression model. Hazard ratios were utilized to investigate the relationship between child mortality and lifetime characteristics identified as significant in the Kaplan-Meier estimate. The hazard function, denoted as h(t), accentuates failure over survival, in contrast to the survival function. The hazard function displays an ascending curve ranging from zero to infinity. Introduced by Cox in 1972, the Cox model stands as the preferred and versatile proportional hazards model for such analyses. For an individual with covariate vectors x, the hazard function at time "t" is expressed as follows:

$h\,(t/X) = h_0(t).\ E\,(X\beta)$

Where,

$X\beta = X_1\beta_1 + X_2\beta_2 + \ldots\ldots\ldots\ldots\ldots + X_p\beta_p$ and $\beta_1, \beta_2, \ldots\ldots\ldots\ldots\ldots, \beta_p$ are the unknown regression coefficients corresponding to the covariate vector $X = (X_1 + X_2 + \ldots\ldots\ldots + X_p)$,

$h_0(t)$ is an arbitrary, unspecified baseline hazard function.

2.4. Interpretation of hazard model

The hazard ratio (HR) serves as a pivotal metric in this study, reflecting the relative likelihood of under-five mortality based on various covariates. An HR of 1 indicates no risk, while an HR greater than 1 signifies an elevated risk, and an HR less than 1 suggests a risk. This metric allows for a nuanced interpretation of how each explanatory variable influences the hazard of under-five deaths.

Ensuring statistical significance is paramount in our analysis. A confidence interval that does not include 1 and a p-value below the thresholds of 0.01, 0.05, or 0.10 are crucial indicators of a significant association between the explanatory variables and under-five mortality. These statistical benchmarks provide a robust foundation to ascertain the impact of each variable, enhancing the reliability of our findings. In essence, by employing hazard ratios and emphasizing statistical significance, our study not only quantifies the relative risks associated with different covariates but also provides a rigorous framework for understanding the strength and direction of these associations. This approach enhances the reliability of our conclusions, aiding researchers and policymakers in making informed decisions to mitigate under-five mortality.

3. Analysis and results

This study is focused on unraveling the factors influencing under-five mortality. Through the application of Cox proportional hazard models, we aim to discern the impact of various covariates on the risk of under-five deaths. Five distinct models are employed, each considering the comprehensive array of explanatory variables. By employing statistical analysis, we seek to elucidate the relationships between these determinants and under-five mortality, offering a nuanced understanding of the complex dynamics at play. This approach allows us to assess the time-to-event outcomes, providing valuable insights into the duration until an under-five death occurs. Through these models, we aspire to contribute to the existing body of knowledge in the field, facilitating a more informed comprehension of the factors that significantly influence under-five mortality rates.

3.1. Utilizing Cox's proportional hazard model, we conducted five distinct analyses as follows

This study employs a systematic approach through five distinct models to unravel the complex determinants of under-five mortality. Each model focuses on specific variables, ranging from socio-economic and environmental factors to demographic, nutritional, and media-related elements. This structured methodology enables a comprehensive understanding of the intricate interplay between diverse factors contributing to under-five mortality.

The Cox Proportional Hazard model, a widely used statistical tool, proves essential in analyzing the time-to-event nature of under-five mortality in Odisha. Leveraging National Family Health Survey (NFHS) data, this model accommodates the time-dependent event, handles censoring in longitudinal studies, and allows for the simultaneous consideration of multiple covariates. Its flexibility, adherence to the proportional hazard assumption, and suitability for population-based studies make it an ideal choice for this analysis.

The study aims to identify significant contributors to under-five mortality in Odisha through Cox's Proportional Hazard models, shedding light on the evolving landscape of U5M risk factors. This statistical exploration, presented in Table 6, delves into hazard ratios across different models, providing a nuanced understanding of the dynamics influencing under-five mortality. These insights serve as a foundation for evidence-based policymaking and targeted interventions to address the changing socio-demographic dynamics impacting child survival in Odisha.

3.2. Results: refer to Table 1

Mothers without education serve as the baseline, indicating a Hazard Ratio (HR) of 1.000. Across education levels, a consistent decrease in hazard ratios is evident in NFHS-5 compared to NFHS-4. Notably, in Model-1, mothers with primary education exhibit a reduction from 0.605 (NFHS-4) to 0.474 (NFHS-5), signaling an improved association between maternal education and under-five mortality (U5M) in NFHS-5. Hazard ratios for male children remain stable across survey rounds, implying a consistent effect. Rural areas consistently exhibit higher hazard ratios than urban areas, with slight reductions in NFHS-5, suggesting a potential decrease in U5M risk in rural regions.
Non-tribal districts consistently show hazard ratios below 1.000, indicating a potential reduction in U5M risk in NFHS-5. Scheduled tribes exhibit mixed hazard ratios, with a slight increase in risk in NFHS-5. Hazard ratios for religion remain stable, indicating a consistent association with U5M across both survey rounds. Hazard ratios for wealth index categories in NFHS-5 generally increase compared to NFHS-4, suggesting a potential rise in U5M risk among wealthier households. Improved toilet facilities and safe cooking fuel continue to be associated with lower U5M risk in NFHS-5.
Hazard ratios for age of mother, birth order, place of delivery, and current breastfeeding exhibit variations between NFHS-4 and NFHS-5. Older mothers and those in the 20-29 age group exhibit lower hazard ratios in NFHS-5, suggesting a potential decrease in U5M risk for these groups. Birth order and place of delivery show varying impacts on U5M risk across both survey rounds. The dynamic changes in hazard ratios between NFHS-4 and NFHS-5 underscore the evolving nature of factors influencing under-five mortality in Odisha. These statistical insights provide a foundation for evidence-based policymaking and targeted interventions to address the shifting landscape of U5M risk factors in the region. Policymakers should consider these statistical nuances to formulate strategies that align with the changing socio-demographic dynamics impacting child survival in Odisha.

Table 1: Significant Contribution of Independent Variable on Dependent Variable (U5M) in Odisha: NFHS Data Analysis (Cox's Proportional Model)

Factors	Specification	Model-1		Model-2		Model-3		Model-4		Model-5	
		NFHS-4	NFHS-5	NFHS-4	NFHS-5	NFHS-4	NFHS-5	NFHS-4	NFHS-5	NFHS-4	NFHS-5
Mothers Education	No Education	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	primary	0.605***	0.474***	0.608***	0.471***	0.597***	0.463***	0.363**	0.501**	0.367**	0.532**
	secondary	0.169***	0.135***	0.17***	0.134***	0.168***	0.123***	0.837	0.338***	0.856	0.374***
	higher	0.074***	0.034***	0.074***	0.034***	0.087***	0.033***	0.855	0.332	0.881	0.357
Sex	Female	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Male	1.038	0.959	1.033	0.959	1.035	0.968	1.112	1.191	1.111	1.196
Place of Residence	Urban	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
rural	Rural	1.217**	0.93	1.24**	0.931	1.296**	0.959	1.559	1.208	1.502	1.284
Region	Tribal District	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	partly tribal district	0.828**	1.018	0.825**	1.029	0.846**	1.033	0.46**	0.445**	0.469**	0.439**
	Non-tribal districts	0.858**	1.276***	0.868**	1.284***	0.926	1.351***	0.813	0.561**	0.821	0.567**
caste	Schedule Caste	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Scheduled tribe	0.838**	0.886	0.841**	0.883	0.85**	0.888	0.927	1.115	0.910	1.025
	other caste	1.048	0.95	1.051	0.941	1.082	0.95	1.208	0.751	1.191	0.693
Religion	Hindu	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	other religion	0.909	0.969	0.870	0.945	0.887	0.941	0.674	0.712	0.665	0.686
Wealth Index	Poor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	poorer	1.241***	1.355***	1.125*	1.211**	1.111	1.200*	0.700	1.647*	0.788	2.308***
	middle	1.261**	1.505***	1.020	1.251*	1.012	1.232	0.24**	0.636	0.292**	1.049
	richer	1.257*	1.194	0.928	0.941	0.921	0.959	0.075**	1.157	0.095**	2.281
	richest	1.66**	1.275	1.179	0.992	1.230	1.039	0.134**	0.961	0.169**	1.998
Toilet Facility	Unimproved			1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Improved			1.024	1.124*	1.026	1.127*	0.870	0.641**	0.850	0.612**
Cooking fuel	Unsafe			1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Safe			1.167	1.094	1.176	1.104	2.257*	0.881	2.267*	0.95
Source of Drinking Water	Unimproved source			1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Improved source			0.897*	0.928	0.898*	0.927	1.266	1.11	1.233	1.195
Floor Material	unsafe			1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	safe			1.241**	0.871*	1.234**	0.871*	0.825	0.686	0.825	0.707
Age of mother at the time of Birth	Less than 20 years					1.000	1.000	1.000	1.000	1.000	1.000
	20-29 years					0.582**	0.612***	0.733*	1.366	0.733*	1.366
	30 years and above					0.307**	0.331***	2.247**	0.298	2.194**	0.298
Birth Order	1st order					1.000	1.000	1.000	1.000	1.000	1.000
	2-3 order					0.842**	0.646***	0.936	0.843	0.925	0.844
	4-6 order					0.848**	0.629***	1.202	0.712	1.175	0.682
	7 and above					0.684*	0.754	0.358	0.776	0.359	0.714
	Home							1.000	1.000	1.000	1.000

Place of Delivery	Institutional	0.822	1.345	0.823	1.376
Currently Breast-feeding	no	1.000	1.000	1.000	1.000
	yes	0.217***	0.166***	0.217***	0.165***
Contraceptive use	Yes	1.000	1.000	1.000	1.000
	using any method of contraceptive	0.697**	0.608**	0.685**	0.607**
Birth-weight	less than 2500gm	1.000	1.000	1.000	1.000
	2500-3500 grams	0.612**	0.379***	0.607**	0.381***
	above 3500grams	1.065	0.531	1.066	0.528
Media Exposure	No			1.000	1.000
	Yes			0.790	0.483***
Covered Health Insurance	no			1.000	1.000
	yes			1.155	0.805

Sig: level of significance, *p<.05, **p<.01, ***p<.001

3.3. Concluding remarks and recommendations

The application of Cox's Proportional Hazard Model in our study, dissected through five distinct models, unravels the intricate dynamics of under-five mortality (U5M) in Odisha. Each model, focusing on different sets of variables, sheds light on the evolving landscape of U5M risk factors, offering valuable insights for policymaking and interventions.

Our findings underscore the positive trend in maternal education, with notable reductions in hazard ratios across education levels in NFHS-5, indicating an enhanced association between education and reduced U5M risk. Stable hazard ratios for male children and decreasing risks in rural areas suggest a consistent effect and a potential decrease in U5M in rural regions. The nuanced exploration of demographic factors reveals varying impacts, emphasizing the significance of non-tribal districts in potentially reducing U5M risk.

The rise in hazard ratios for wealthier households in NFHS-5 suggests a concerning trend, necessitating targeted interventions to address U5M risk among wealthy populations. Concurrently, the enduring protective influence of improved toilet facilities and safe cooking fuel emphasizes the importance of infrastructural elements in mitigating U5M risk.

Exploring maternal and birth-related factors unravels complexities in age, birth order, and delivery location, emphasizing the need for tailored strategies to address diverse risk profiles. The dynamic nature of hazard ratios between NFHS-4 and NFHS-5 highlights the evolving landscape of U5M determinants.

Policymakers are urged to leverage these statistical nuances to formulate evidence-based strategies and interventions. Targeted efforts should align with the changing socio-demographic dynamics, ensuring effective and tailored approaches to tackle U5M in Odisha. Our study's comprehensive approach, incorporating socio-economic, environmental, demographic, nutritional, and media-related variables, positions these findings as a robust foundation for informed policy decisions aimed at advancing child survival in the region.

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