

Original Research Article

Infant mortality in India: a statistical study using survival and regression methods based on national family health survey data

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ABSTRACT

Background: Although infant mortality in India has declined substantially over the past three decades, large social and regional inequalities persist. This study examines long-term trends in infant mortality and quantifies caste-based differentials in infant survival, with special focus on Uttar Pradesh, Madhya Pradesh, and Maharashtra.

Methods: Data from all five rounds of the National Family Health Survey (NFHS-1 to NFHS-5; 1992-2021) were used to assess trends in infant mortality. Survival and regression analyses were conducted using NFHS-5 (2019-21). The study included live births occurring in the five years preceding the survey. Infant survival was examined using Kaplan-Meier estimates and log-rank tests. Binary logistic regression models assessed the association between caste and infant mortality after adjusting for socio-economic, demographic, and healthcare factors, accounting for survey design.

Results: At the national level, infant mortality in 2019-21 was higher among Scheduled Tribes (ST) (41.6 per 1,000) and scheduled castes (SC) (40.7 per 1,000) than among non-SC/ST infants (32.8 per 1,000). Survival analysis showed significant caste differences in infant survival ($\chi^2=15.02$, $p<0.001$), with higher hazards concentrated in the early months of life. In unadjusted models, SC infants had significantly higher odds of death (OR=1.26; 95% CI: 1.19-1.33), which remained modest but significant after full adjustment (OR=1.09; 95% CI: 1.01-1.18). ST disadvantage was attenuated after adjustment. Maternal education, household wealth, ≥ 4 antenatal care visits (OR \approx 0.65), and institutional delivery were strongly protective. Uttar Pradesh and Madhya Pradesh showed persistently high infant mortality, while Maharashtra exhibited lower overall risk but residual tribal disadvantage.

Conclusions: Despite sustained declines in infant mortality, caste and regional inequities remain pronounced in India. Strengthening equitable access to quality maternal and newborn care is essential for further reductions.

Keywords: Infant mortality, Caste inequality, Survival analysis, Maternal health, NFHS, India

INTRODUCTION

Infant mortality is one of the commonly used parameters for assessing the health and development of a population, reflecting underlying socio-economic and policy factors.^{1,2} India has registered a significant decline in the infant mortality rate (IMR) over the last three decades, largely due to improvements in immunization coverage,

maternal and newborn health, nutrition, and sanitation. Yet, IMRs remain higher for socially disadvantaged groups, such as SCs and STs.^{3,4}

The NFHS-5 (2019-21) survey indicates an IMR of 32 per 1,000 live births, lower than the 57 recorded in 2005-06. Despite the decline, IMRs remain high for certain groups, with those in poor households facing twice the

risk of death as those in richer households, and caste differences persist even after accounting for socio-economic differences. State-wise differences also emphasize the uneven progress made in this regard. For instance, Kerala and Tamil Nadu have low IMRs due to the quality of public healthcare and high female literacy, while Uttar Pradesh and Madhya Pradesh are still registering higher IMRs compared to the national average. Even in Maharashtra, there are rural-urban and social group differences, indicating that economic growth does not guarantee a low IMR.

The persistence of inequalities is also related to the lack of access to quality healthcare, the low uptake of antenatal and postnatal care, and education, income, and social group inequalities. The recent challenges caused by the COVID-19 pandemic have also impacted the progress made in neonatal and infant mortality, especially in weaker-performing states.^{12,13}

This study examines trends and socio-economic differentials in infant mortality in India, with a focused analysis of Maharashtra, Uttar Pradesh, and Madhya Pradesh. Using NFHS data and survival analysis methods, it identifies key demographic, socio-economic, and healthcare determinants of infant survival and discusses policy implications for reducing persistent social and regional inequalities.

Literature review

Trends in infant mortality

India has shown a reduction in IMR from about 80 deaths per 1,000 live births in 1990 to 32 deaths in 2021. This reduction has been a result of the impact of large-scale public health programs, improvements in maternal healthcare, and female educational status.^{14,15} Although the decline in infant mortality has been significant, it has slowed down in some of the high-burden states, including UP and MP. In contrast, urban centers have shown a greater decline in infant mortality compared to rural areas, where access to healthcare facilities is a challenge.^{17,18}

Determinants of infant mortality

Socio-economic status has been a major factor associated with infant deaths. Poverty has a significant impact on infant health, leading to increased infant deaths.^{7,19} Maternal educational status has a strong impact on infant health outcomes. Maternal educational status has a significant impact on infant health outcomes.^{18,20} Maternal age, high birth order, and short birth intervals are some of the demographic factors associated with infant deaths.²¹

Antenatal care has a significant impact on infant health outcomes.^{2.3} Caste and regional inequalities.^{8,19}

The role of caste in determining IMRs persists in India. SC and ST infants face a greater risk of mortality compared to other infants even when adjusting for socio-economic factors.^{6,22} This is partly due to the structural factors of discrimination and geographic isolation.^{3,11} Uttar Pradesh and Madhya Pradesh have high mortality rates, whereas Maharashtra has a significant but reduced caste differential in mortality rates.^{9,10}

METHODS

Study design and data source

The study is a cross-sectional analytical study conducted using secondary data collected from the NFHS, conducted by the Ministry of Health and Family Welfare, Government of India, with technical assistance from the International Institute for Population Sciences (IIPS). The study is conducted using five rounds of the NFHS: NFHS-1 (1992-93 to NFHS-5 (2019-21). The study is conducted using a stratified multistage sampling design to represent the country as well as the states.

Study setting and period

The study setting is India at the national level. Three states were selected for focused analysis: Uttar Pradesh, Madhya Pradesh, and Maharashtra. The study period is for nearly three decades from 1992 to 2021.

Study population and inclusion criteria

The study population is all births that occur within five years preceding each survey to avoid recall bias. Infant mortality is death before the completion of 12 months of age. Children are divided into three social groups: SC, ST, and non-SC/ST.

Variables and measurements

The main variable of interest is infant mortality-death of infants before they reach one year of age. Other variables of interest are demographic variables (sex of the infant, birth order, birth interval, maternal age), socio-economic variables (maternal education, household wealth index, place of residence), and healthcare variables (antenatal care utilization and place of delivery).

Statistical analysis

The statistical analysis of the study is carried out in three steps. First, estimates of infant mortality were done for different castes, states, and socio-economic variables. Then, trends were checked across different NFHS rounds. Secondly, Kaplan-Meier estimates of survival were carried out to compare the survival of infants across different social groups. Thirdly, logistic regression analysis is carried out to estimate the independent effects of caste, socio-economic variables, demographic variables, and healthcare variables on infant mortality.

Ethical considerations

The study uses anonymous publicly available NFHS data from the DHS program. The study does not require approval from ethics committees as it uses anonymous publicly available data. The NFHS study has been approved by the IIPS and the Ministry of Health and Family Welfare for each of the NFHS rounds.

RESULTS

Trends and patterns in infant mortality

Table 1 illustrates the trend of the decline in the IMR in India, spanning from 1992-93 to 2019-21. The trend shows a constant improvement in all caste groups. In the years spanning from 1992-93, the national IMR was at a high of 78.5 deaths per 1,000 live births, while it was higher at 96.7 deaths per 1,000 live births in the SCs and at 85.0 deaths per 1,000 live births in the STs. In the years spanning from 2019-21, the IMR has declined to 35.2 deaths per 1,000 live births, showing a significant improvement in all groups. Nevertheless, the IMR in SCs stands at a high of 40, while it stands higher at over 45 in STs, compared to that in non-SC/non-ST, which stands at a lower rate of 32.

Table 2 illustrates the trends in IMR at the state level, covering UP, MP, and Maharashtra. All states show a sharp decline in IMR since NFHS-1. Nevertheless, the rate of decline is higher in Maharashtra, with a significantly lower IMR than the national mean, while UP and MP are still high-burden states, with IMR higher than the national mean, reflecting inter-state inequality. The differences in these states, with regard to caste and tribe, are depicted in Table 3. While the rate of decline in infant mortality is present in every caste or tribe, the rate of decline is lower in SC and ST infants, particularly in UP and MP, where the gap is large. In Maharashtra, the gap is narrowing but not closing completely.

The rate of decline in infant mortality is high, but the influence of social identity is also evident. This emphasizes the importance of special attention to the health of disadvantaged women.

Infant mortality by socio-economic and demographic characteristics

Table 4 presents the IMR for various socio-economic and demographic groups for India, Uttar Pradesh, Madhya Pradesh, and Maharashtra, based on the NFHS-5 survey conducted between 2019 and 2021. Inequalities exist in the IMR for residence, caste, wealth, education, mother's profile, and healthcare.

Residence: Rural infants have higher mortality rates. Rural IMRs in UP and MP exceed 50/1000, whereas urban IMRs are around 42-44. In Maharashtra, the

difference between rural and urban IMRs is less pronounced.

Caste

Scheduled Caste and Scheduled Tribe infants have the highest IMRs. In UP, the IMRs for SC infants are approximately 58, whereas for other infants, the IMRs are 47. In MP, the IMRs for ST infants are 41, whereas for non-SC/ST infants, the IMRs are 39. In Maharashtra, the IMRs for ST infants are 31, whereas for non-SC/ST infants, the IMRs are 22.

Wealth

As the wealth increases, the IMRs decrease sharply. Infants in poor households have approximately double the mortality rates of infants in the richest households. For instance, the IMRs in UP are 58 for poor households, whereas for the richest households, the IMRs are 37. Similarly, the IMRs in MP. Maternal Education: This factor remains highly protective. For uneducated mothers, IMR >55 in UP and 49 in MP, whereas for mothers with higher education, IMR 33.

Maternal age and birth order

For young mothers (<25 years) and high birth order (4+), IMR >60 in UP, significantly higher than 1st/2nd births.

Healthcare utilization

Antenatal care and institutional delivery significantly reduce infant deaths. In UP, IMR=63 when there is no ANC, whereas when there is ≥ 4 visits, IMR=28. In MP, IMR=68 when home delivery is the only option, whereas when institutional delivery is the option, IMR=39.

In all states, socio-economic inequality, caste, and health-service issues continue to play the most important role in determining IMRs despite overall improvements.

Survival analysis: cumulative hazard functions

Figure 1 displays cumulative hazard plots for infant mortality by caste groups for all India and states. At the all-India level, it is seen that SC and ST have higher hazards than others, with their plots rising steeply in the initial months, suggesting higher mortality soon after birth. Non-SC/ST always has the lowest risk.

At the state level, it is seen that for Uttar Pradesh, the risk is higher for SC, especially in the first 28 days. In Madhya Pradesh, the risk is higher for ST throughout infancy, suggesting that they have been at a disadvantage. In Maharashtra, gap is least, though still higher for ST.

The survival analysis has thus re-confirmed that infant mortality is influenced by social factors, with SC and ST still at higher risk despite improvements in IMRs.

Equality of survivor functions: log-rank tests

Table 5 displays the log-rank test for the comparison of infant survival across caste groups.

At the national level, the survival differences are statistically significant, confirming the hypothesis that SC and ST infants are exposed to greater mortality risks than non-SC/ST infants.

At the state level, the test for UP shows statistically significant survival differences for infants, indicating the presence of substantial inequality in the first year of life. In contrast, the test for MP does not reveal statistically significant survival differences for infants, suggesting that the survival gaps in the first year of life are less substantial. In Maharashtra, no statistically significant survival differences were detected, which is in line with the small survival gaps observed in the data.

In UP and MP, the sample sizes for the ST group are relatively small. Therefore, the non-significant test results should be interpreted as inconclusive rather than indicating equal survival outcomes.

The following tables represent the results of the Log-rank test for the equality of survivor functions for IMR for SC, ST, and non-SC/ST in India and various states, 2019-21.

Summary of findings from survival analysis

The analysis confirms that SC/ST infants have excess mortality than the non-SC/ST groups. In Uttar Pradesh, inequalities exist in the first year of life, particularly in the neonatal period. In Madhya Pradesh, excess mortality continues throughout infancy, with disadvantage in tribal areas. In Maharashtra, the survival rates are almost equal, but ST infants have excess mortality.

IMRs have decreased, but inequalities remain. States must have special programs for newborn care, including stronger focus on the neonatal period in Uttar Pradesh, tribal support in Madhya Pradesh, and addressing the hard-to-reach groups in Maharashtra.

Multivariate analysis of infant mortality

A set of logistic regression models was developed to evaluate the effect of various factors, including caste, socio-economic, and health-related factors, on infant mortality. Four models have been developed, starting from the crude differences between castes to the fully adjusted model.

At the national level, SC infants have 9% higher odds of mortality under one year of age than their counterparts from other castes, even after full adjustment. However, the odds of mortality for ST infants decrease after the full adjustment, indicating that the risk factors for ST operate through the socio-economic and healthcare factors.

Among the socio-economic factors, the most important factors for reducing the odds of mortality for infants are those related to education, followed by wealth. Having four or more antenatal care sessions reduces the odds of mortality for infants by one-third, whereas institutional delivery also provides an added advantage. Short birth intervals and high birth order remain important risk factors.

State-level patterns

Uttar Pradesh (Table 7): Caste factors are attenuated in the adjusted models, while maternal education and ANC use are the strongest predictors. Educated women or those with 4+ ANC visits are 25 to 50 percent less likely to lose an infant.

Madhya Pradesh (Table 8): At first, ST status is a risk factor, but this is no longer apparent in the adjusted models. ANC use, maternal education, and wealth are strong predictors of survival; while having a fourth or higher birth increases risk.

Maharashtra (Table 9): In Maharashtra, the initial disadvantage among ST infants disappears in the adjusted models. Education, wealth, and ANC use are consistently protective, although the small sample sizes limit the precision of the findings.

Summary of regression findings

Infant mortality inequalities persist mainly through education, wealth, and healthcare access. Caste and tribe influence remains, but once these mediating factors are considered, their direct impact weakens. States need differentiated strategies: improved maternal care and education in UP, strengthened tribal health outreach in MP, and targeted inclusion of remote communities in Maharashtra.

Table 1: IMR by social groups in India (1992-93 and 2019-21).

Social group	1992-93	2019-21
Total India	78.5	35.2
SC	96.7	40
ST	85	41
Non-SC/ST	75	32

Table 2: Trends in IMR in selected states (1992-93 to 2019-21).

Years	Uttar Pradesh	Madhya Pradesh	Maharashtra
1992-93	100	85	50
1998-99	87	87	44
2005-06	73	70	37
2015-16	64	51	24
2019-21	50	41	23

Table 3: Percentage change in IMR by social groups (1992-93 to 2019-21).

Region	SC (%)	ST (%)	Non-SC/ST (%)
India	-58	-51	-56
Uttar Pradesh	-55	-65	-50
Madhya Pradesh	-53	-57	-51
Maharashtra	-73	-47	-54

Table 4: IMR by mother's socio-economic and demographic characteristics in U. P., M. P., Maharashtra.

Background characteristics	India	Uttar Pradesh	Madhya Pradesh	Maharashtra
Residence				
Urban	26.5564	41.9696	33.8689	22.5804
Rural	38.3579	52.5495	43.4737	23.7066
Religion				
Hindu	35.9566	51.5902	41.4657	22.2303
Muslim	33.3164	45.1081	39.293	30.1982
Christian	27.7151	58.4887	0	37.3497
Others	29.1039	35.954	43.9114	17.5387
Caste				
SC	40.6779	57.7638	48.1874	21.0795
ST	41.6452	57.5636	41.2784	31.0634
Non-SC/STs	32.7976	47.1529	39.0416	22.4145
Wealth quintile				
Poor	44.6848	57.8785	47.5166	33.6263
Middle	33.6596	50.6301	33.5753	21.6269
Rich	23.1814	37.1371	32.5195	18.6315
Mother's education				
No education	49.2035	57.9102	48.7597	12.251
Primary	43.1467	58.1825	47.8732	42.1059
Secondary	31.9348	48.9038	39.8853	21.8872
Higher	19.6777	33.4225	23.869	23.1183
Mother's age (in years)				
15-24	40.3085	62.6236	43.7298	27.0617
25-34	32.2422	45.5406	38.0352	22.3007
35-49	36.8355	49.9429	60.7568	14.4499
Birth order				
1	35.449	54.2664	43.9011	22.0898
2-3	31.2061	43.3439	37.7077	23.5609
4 or more	50.5621	61.4345	47.9121	27.7449
Sex of child				
Male	37.4009	51.5259	45.3575	24.4873
Female	32.8156	49.1311	37.001	21.867
ANC visit				
No ANC	35.2651	62.738	38.1745	14.6917
Partial (1-3)	28.9208	40.0264	29.8723	9.9508
4+ ANC	18.9306	28.503	23.9957	16.5661
Place of delivery				
Home	51.7788	59.6796	68.4296	33.3747
Institutional	33.165	48.6608	38.6254	22.6502

Table 5: Log-rank test.

Caste	Event observed	Event expected	Caste	Event observed	Event expected
India			Uttar Pradesh		
SC	550	476.66	SC	170	152.25
ST	441	448.09	ST	19	10.76
Non-SC/STs	1182	1248.25	Non-SC/STs	365	390.99
Total	2173	2173	Total	554	554

Continued.

Caste	Event observed	Event expected	Caste	Event observed	Event expected
Madhya Pradesh			Maharashtra		
SC	36	34.95	SC	13	9.61
ST	61	53.85	ST	11	10.76
Non-SC/STs	97	105.2	Non-SC/STs	31	34.63
Total	194	194	Total	55	55

* $\chi^2(1)=15.02, p=0.0005$ (India), $\chi^2(1)=10.21, p<0.0061$ (U.P.). $\chi^2(1)=1.63, p=0.4425$ (M.P.) and $\chi^2(1)=1.59, p=0.4514$ (Maharashtra).

Table 6: Association (odds) and logit estimates of infant death risk by different characteristics in India, 2019-21.

Variables	Model-I (Unadjusted OR)	Model-II socio-economic (Adjusted OR)	Model-III proximate (Adjusted OR)	Model-IV-full model (Adjusted OR)
Place of residence				
Urban®				
Rural		1.10** [1.03,1.18]		1.04 [0.95,1.15]
Caste				
Non-SC/ST®				
SC	1.26*** [1.19,1.33]	1.12*** [1.06,1.19]	1.14** [1.05,1.23]	1.09* [1.01,1.18]
ST	1.05 [0.99,1.11]	0.96 [0.90,1.03]	0.92* [0.84,1.00]	0.97 [0.88,1.07]
Religion				
Hindu®				
Muslim		0.88*** [0.81,0.95]		0.89* [0.80,0.99]
Christian		0.69*** [0.62,0.77]		0.63*** [0.54,0.73]
Others		0.81** [0.71,0.92]		0.79** [0.66,0.94]
Wealth status				
Poor®				
Middle		0.80*** [0.75,0.85]		0.81*** [0.74,0.89]
Rich		0.70*** [0.65,0.75]		0.71*** [0.65,0.79]
Maternal age (in years)				
15-24®				
25-34			0.75*** [0.70,0.81]	0.79*** [0.73,0.86]
35-49			0.86* [0.76,0.97]	0.95 [0.84,1.07]
Maternal education level				
No education®				
Primary		0.93 [0.87,1.00]	0.93 [0.84,1.03]	0.99 [0.89,1.09]
Secondary		0.74*** [0.70,0.79]	0.70*** [0.64,0.76]	0.79*** [0.72,0.86]
Higher		0.53*** [0.48,0.59]	0.47*** [0.41,0.53]	0.58*** [0.50,0.67]
Birth order				
1®				
2-3			0.86*** [0.79,0.93]	0.84*** [0.78,0.91]
4 or more			1.34*** [1.20,1.50]	1.30*** [1.16,1.45]
Sex of child				
Male®				
Female			0.89*** [0.83,0.95]	0.89*** [0.83,0.95]
ANC visits				
No ANC®				
Partial			0.83** [0.75,0.93]	0.81*** [0.72,0.90]
4+ANC			0.66*** [0.59,0.73]	0.65*** [0.58,0.73]
Place of delivery				
Home®				
Institutional			0.89* [0.81,0.98]	0.89* [0.81,0.98]

*Note: ## denote low sample either no sample.

Table 7: Association (odds) and logit estimates of infant death risk by different characteristics U. P., 2019-21.

Variables	Model-I (Unadjusted OR)	Model-II socio-economic (Adjusted OR)	Model-III proximate (Adjusted OR)	Model-IV- full model (Adjusted OR)
Place of residence				
Urban®				
Rural		1.07 [0.86,1.17]		0.91 [0.73,1.12]

Continued.

Variables	Model-I (Unadjusted OR)		Model-II socio-economic (Adjusted OR)		Model-III proximate (Adjusted OR)		Model-IV- full model (Adjusted OR)	
Caste								
Non-SC/ST®								
SC	1.17**	[1.05,1.30]	1.06	[0.95,1.18]	1.05	[0.91,1.22]	1.0	[0.85,1.17]
ST	1.21	[0.86,1.70]	1.07	[0.76,1.51]	1.19	[0.76,1.86]	1.12	[0.71,1.76]
Religion								
Hindu®								
Muslim			0.9	[0.78,1.03]			0.92	[0.76,1.11]
Christian								
Others			0.24	[0.03,1.74]				
Wealth status								
Poor®								
Middle			0.92	[0.81,1.05]			0.9	[0.75,1.08]
Rich			0.74***	[0.64,0.86]			0.75**	[0.61,0.91]
Maternal age (in years)								
15-24®								
25-34					0.69***	[0.58,0.82]	0.71***	[0.59,0.84]
35-49					0.69**	[0.53,0.90]	0.71*	[0.55,0.93]
Maternal education level								
No education®								
Primary			1.05	[0.91,1.22]	1.03	[0.81,1.23]	1.01	[0.82,1.25]
Secondary			0.88*	[0.79,1.00]	0.86	[0.73,1.02]	0.89	[0.75,1.06]
Higher			0.69***	[0.58,0.83]	0.61***	[0.47,0.78]	0.67**	[0.51,0.87]
Birth order								
1®								
2-3					0.81*	[0.68,0.97]	0.80*	[0.67,0.95]
4 or more					1.31*	[1.04,1.65]	1.27*	[1.01,1.60]
Sex of child								
Male®								
Female					1.04	[0.91,1.18]	1.04	[0.91,1.18]
ANC visits								
No ANC®								
Partial					0.65***	[0.52,0.83]	0.66***	[0.52,0.84]
4+ANC					0.50***	[0.39,0.65]	0.52***	[0.40,0.66]
Place of delivery								
Home®								
Institutional					1.02	[0.85,1.22]	1.03	[0.85,1.24]

*Note: ## denote low sample either no sample.

Table 8: Association (odds) and logit estimate of infant death risk by different characteristics in Madhya Pradesh, 2019-21.

Variables	Model-I (Unadjusted OR)		Model-II socio-economic (Adjusted OR)		Model-III proximate (Adjusted OR)		Model-IV-full model (Adjusted OR)	
Place of residence								
Urban®								
Rural			0.82	[0.65,1.04]			0.72	[0.52,1.00]
Caste								
Non-SC/ST®								
SC	1.23*	[1.00,1.50]	1.14	[0.92,1.40]	1.26	[0.94,1.69]	1.24	[0.92,1.67]
ST	1.05	[0.87,1.26]	0.91	[0.75,1.11]	0.97	[0.73,1.29]	0.94	[0.69,1.27]
Religion								
Hindu®								
Muslim			1.20	[0.70,1.44]			1.31	[0.82,2.09]
Christian			##	##			##	##
Others			1.14	[0.50,2.61]			1.33	[0.41,4.27]
Wealth status								
Poor®								
Middle			0.66**	[0.51,0.85]			0.68*	[0.47,0.97]
Rich			0.75*	[0.58,0.96]			0.71	[0.50,1.01]

Continued.

Variables	Model-I (Unadjusted OR)	Model-II socio-economic (Adjusted OR)	Model-III proximate (Adjusted OR)	Model-IV-full model (Adjusted OR)
Maternal age (in years)				
15-24®				
25-34			0.82 [0.63,1.08]	0.83 [0.63,1.09]
35-49			1.70* [1.06,2.73]	1.68* [1.04,2.71]
Maternal education level				
No education®				
Primary		1.03 [0.80,1.32]	1.28 [0.88,1.86]	1.3 [0.89,1.89]
Secondary		0.92 [0.76,1.13]	1.03 [0.75,1.42]	1.08 [0.78,1.50]
Higher		0.66* [0.45,0.98]	0.7 [0.41,1.18]	0.76 [0.43,1.33]
Birth order				
1®				
2-3			0.54*** [0.41,0.71]	0.53*** [0.40,0.70]
4 or more			0.75 [0.50,1.14]	0.73 [0.48,1.11]
Sex of child				
Male®				
Female			0.79* [0.62,0.99]	0.78* [0.62,0.99]
ANC visits				
No ANC®				
Partial			0.63* [0.41,0.97]	0.63* [0.41,0.97]
4+ANC			0.57** [0.37,0.87]	0.58* [0.38,0.89]
Place of delivery				
Home®				
Institutional			0.71 [0.49,1.02]	0.73 [0.50,1.04]

*Note: ## denote low sample either no sample.

Table 9: Association (odds) and logit estimates of infant death risk by different characteristics in Maharashtra, 2019-21.

Variables	Model-I (Unadjusted OR)	Model-II socio-economic (Adjusted OR)	Model-III proximate (Adjusted OR)	Model-IV-full model (Adjusted OR)
Place of residence				
Urban®				
Rural		0.98 [0.69,1.41]		0.95 [0.57,1.58]
Caste				
Non-SC/ST®				
SC	1.19 [0.84,1.70]	1.09 [0.71,1.66]	1.18 [0.72,1.95]	1.07 [0.59,1.94]
ST	1.50* [1.09,2.07]	1.39 [0.97,1.98]	1.41 [0.86,2.31]	1.24 [0.74,2.09]
Religion				
Hindu®				
Muslim		1.24 [0.79,1.95]		1.39 [0.75,2.59]
Christian		1.54 [0.21,11.48]		## ##
Others		1.09 [0.61,1.97]		1.16 [0.51,2.61]
Wealth status				
Poor®				
Middle		0.70* [0.50,1.00]		0.63 [0.38,1.03]
Rich		0.54** [0.37,0.78]		0.47** [0.28,0.81]
Maternal age (in years)				
15-24®				
25-34			0.71 [0.46,1.09]	0.73 [0.48,1.13]
35-49			0.71 [0.30,1.68]	0.75 [0.32,1.78]
Maternal education level				
No education®				
Primary		2.34* [1.14,4.80]	2.35 [0.78,7.11]	2.3 [0.76,6.93]
Secondary		2.57** [1.36,4.86]	3.13* [1.17,8.38]	3.56* [1.33,9.49]
Higher		1.88 [0.86,4.11]	2.19 [0.69,6.94]	3.1 [0.96,10.01]
Birth order				
1®				
2-3			1.43 [0.90,2.26]	1.35 [0.85,2.14]
4 or more			2.51* [1.18,5.33]	2.07 [0.96,4.46]
Sex of child				
Male®				
Female			0.87 [0.59,1.27]	0.87 [0.60,1.27]

Continued.

Variables	Model-I (Unadjusted OR)	Model-II socio-economic (Adjusted OR)	Model-III proximate (Adjusted OR)	Model-IV-full model (Adjusted OR)
ANC visits				
No ANC®				
Partial			0.56 [0.28,1.12]	0.57 [0.28,1.14]
4+ANC			0.61 [0.34,1.11]	0.64 [0.35,1.16]
Place of delivery				
Home®				
Institutional			0.64 [0.31,1.30]	0.7 [0.34,1.42]

*Note: ## denote low sample either no sample.

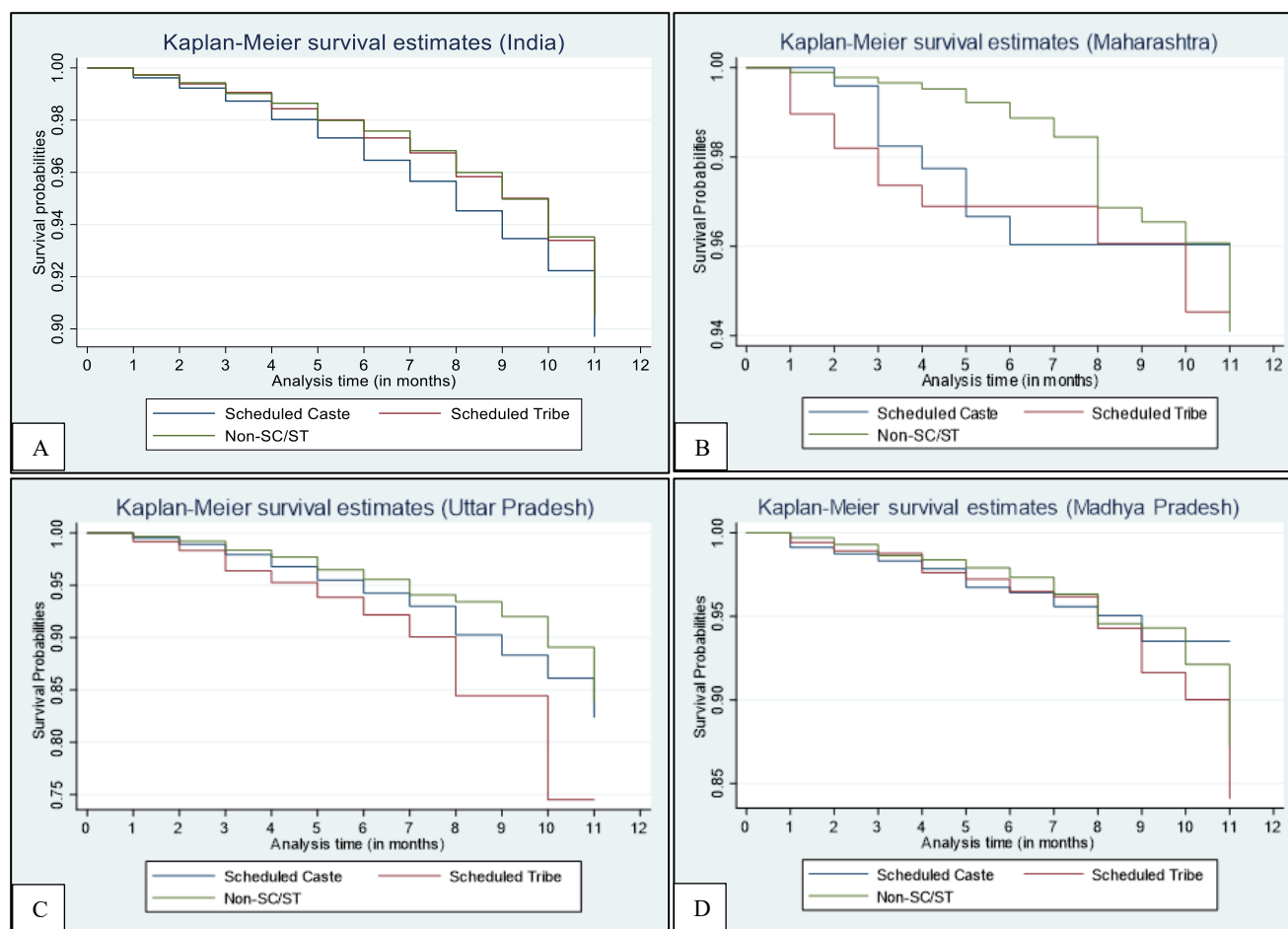


Figure 1 (A-D): Cumulative hazard functions (infant mortality) for SC, ST, and non-SC/ST populations in India, Uttar Pradesh, Madhya Pradesh, and Maharashtra, NFHS-5, 2019-21.

DISCUSSION

There has been a marked improvement in infant mortality in India over the past three decades, with IMR reducing from approximately 78 deaths per 1,000 live births in 1992-93 to approximately 35 in 2019-21. The results are in accordance with national survey findings and previous research on improvements in maternal and child health facilities in India.^{5,15} Despite this improvement, there are inter-state disparities, with Maharashtra having the lowest IMR, while Madhya Pradesh and Uttar Pradesh have higher IMR values. The results are in accordance with previous research on infant mortality in India, where some states have higher IMR values due to poor health facilities and socio-economic factors.^{8,9}

The current study shows that SC and ST infants have higher mortality risks compared to non-SC/ST infants. The results are in accordance with previous research on infant mortality in India, where there are inequalities in infant mortality between SC/ST and non-SC/ST infants.^{3,4,7}

The results from the survival analysis show that the inequalities in infant mortality are most marked in the initial months in Uttar Pradesh, while in Madhya Pradesh and Maharashtra, inequalities in infant mortality between tribal and non-tribal infants are marked throughout infancy. Similar findings have been reported in earlier studies where neonatal mortality contributes substantially to overall differences.⁸

Strong socio-economic gradients in infant mortality were observed, with higher mortality among infants born to poor, uneducated, and rural mothers. These findings align with earlier studies emphasizing the role of socio-economic disadvantage in shaping child survival outcomes.^{7,18,19} Maternal education emerged as a key protective factor, consistent with previous research.¹⁸

Healthcare utilization plays a crucial role in reducing infant mortality. Adequate antenatal care significantly lowers mortality risk, while institutional delivery also provides protection, although its impact is weaker in Uttar Pradesh, possibly due to quality-of-care issues. These findings are consistent with earlier studies demonstrating the importance of maternal healthcare services.^{8,18} Survival analysis further confirms that most inequalities occur during the neonatal period.

Regression analysis shows that the direct effect of caste diminishes after adjusting for socio-economic and healthcare factors, indicating that caste disparities operate through these mediating variables. Similar patterns have been reported in previous studies.^{4,7} Maternal education, household wealth, and antenatal care remain the strongest protective factors.

Overall, while India has made significant progress in reducing infant mortality, inequalities persist across social and regional groups. Targeted interventions focusing on maternal education, improved antenatal care, and equitable healthcare access are essential for further reduction in infant mortality, particularly in high-burden states such as Uttar Pradesh and Madhya Pradesh.

CONCLUSION

This study demonstrates that infant mortality in India has reduced significantly over the last three decades, though there are considerable disparities in the population. In this context, the study on the data collected by the NFHS between 1992 and 2021 has revealed that though the IMR in the country has reduced significantly, the IMR in Uttar Pradesh and Madhya Pradesh is still high, while in Maharashtra it is improving.

Infants belonging to the SC and ST populations are also at a higher risk of mortality, and this is due to the socio-economic disadvantages faced by them in terms of low literacy levels, poverty, and living in the rural areas. Although health service utilisation, especially antenatal care, greatly reduces the risk of infant mortality, its impact is limited by the low coverage and quality of services in poorer states.

To further reduce infant mortality, targeted interventions are needed, focusing on particular states and services. Key interventions include upgrading the quality of neonatal and delivery care in Uttar Pradesh, strengthening antenatal and outreach services in tribal areas of Madhya Pradesh, and rural and tribal areas of Maharashtra.

To make further progress, education levels of women need to improve, and the general standard of living needs to be enhanced, with equitable access to quality maternal and infant health services.

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