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Ecological Epidemiology of Neonatal Vulnerability in India

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Abstract

Background: India bears a disproportionate share of the global burden of preterm (PT) and low birth-weight (LBW) births, yet nationally representative, multi-period evidence on their distribution and associated health outcomes has remained limited. This study maps the ecological epidemiology of neonatal vulnerability across India's public health system and examines its association with key neonatal health outcomes at the district level.

Methods: District-level data for 2017–18 and 2022–23 were extracted from India's Health Management Information System (HMIS), covering over 29 million live births across 703 and 757 districts, respectively. PT and LBW birth rates were used as indicators of neonatal vulnerability. Their associations with caesarean section rates, breastfeeding initiation within one hour, Sick Newborn Care Unit (SNCU) admissions and mortality, and infant mortality across early, late, and post-neonatal periods were examined using ANOVA and simple linear regression models.

Results: Over the five-year period, PT and LBW birth rates increased across the majority of India's states and union territories, and the concentration of high-burden districts grew substantially. By 2022–23, districts bearing the greatest neonatal burden reported consistently worse outcomes across every metric examined, including infant mortality rates approximately double those in low-burden districts.

Conclusion: These findings reveal a widening geographic concentration of neonatal vulnerability and its downstream health consequences in India's public health facilities. Addressing this trend requires strengthening the continuum of care for vulnerable newborns - including improving HMIS data quality, integrating pre-conception and antenatal nutrition into routine care, expanding donor human milk access, and enhancing SNCU capacity - with priority attention to high-burden states and districts.

Keywords

Health Management Information System (HMIS), Low Birthweight, Neonatal Vulnerability, Preterm Birth.

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Introduction

Globally, preterm (PT) birth and low birth-weight (LBW) remain the leading proximate causes of neonatal morbidity and mortality, with infants born too soon or too small carrying a two- to ten-fold higher risk of death compared to term, normal-weight newborns (Saigal & Doyle, 2008; WHO, 2019). Achieving SDG target 3.2 (reducing neonatal mortality to 12 or fewer per 1,000 live births by 2030) is therefore contingent on decisive action against these two conditions (Darmstadt et al., 2012).

India's position within this global landscape is particularly concerning. In 2020, India recorded 3.02 million PT births, the highest absolute number worldwide, accounting for over 23% of all preterm births globally (WHO, 2023). UNICEF-WHO 2023 estimates place India as having the largest proportion of LBW newborns (27.4%) with 6.4 million affected annually, firmly ranking the country among the top five nations for both indicators. The aetiology of PT and LBW births is multifactorial, spanning maternal undernutrition and micronutrient deficiency, reproductive tract infections, chronic disease, extreme paternal age, short inter-pregnancy intervals, multiple gestations, intrauterine growth restriction, and genetic predisposition, alongside non-medically indicated caesarean delivery (Pusdekar et al., 2020; Shah, 2010; Faye-Petersen, 2008).

The consequences are severe and far-reaching. Nationally, prematurity and LBW together account for 45.5% of all early neonatal deaths in India (SRS Cause of Death Report, 2017–19)[3]. Beyond mortality, these conditions compromise neurodevelopment, immune function, lung maturation, and nutritional status, imposing long-term disability burdens that demand resilient health systems capable of supporting vulnerable newborns well beyond the immediate neonatal period (Luu et al., 2017). Survival disparities between high-income countries and resource-limited settings remain stark, underscoring the outsized toll borne by low- and middle-income countries (LMICs) (Kleinhout et al., 2021).

India has pursued these challenges through a range of National Health Mission (NHM) initiatives spanning preconception through postnatal care, including Anemia Mukt Bharat, the Pradhan Mantri Surakshit Matritva Yojana (PMSMA), Janani Shishu Suraksha Karyakram (JSSK), Kangaroo Mother Care (KMC), and Home-Based Newborn Care (HBNC). At the facility level, over 1,039 Sick Newborn Care Units (SNCUs) and NICUs are now operational nationally, with a growing network of Comprehensive Lactation Management Centres (CLMCs) to support donor human milk (DHM) feeding for vulnerable neonates. These efforts are aligned with Every Newborn Action Plan (ENAP), which has guided newborn health policy across more than 194 countries for over a decade (Mason et al., 2014; WHO, 2022).

Yet India's persistent ranking among the highest-burden countries for PT and LBW births raises urgent questions about the adequacy of current programmatic response. A fundamental constraint is the absence of

[3] *Office of the Registrar General & Census Commissioner, India (2023). Sample Registration System (SRS) - Cause of Death in India 2017-2019. Ministry of Home Affairs, Government of India.* https://censusindia.gov.in/nada/index.php/catalog/44752

routine, systematic recording of gestational age and birth weight across health facilities - metrics that are indispensable for identifying vulnerable neonates and guiding targeted care (Okwaraji et al., 2024; Ohuma et al., 2023). Without reliable sub-national epidemiological data, designing and evaluating effective interventions remains difficult.

Existing evidence from LMICs on neonatal vulnerability is largely confined to single-site or single-year studies. In India, direct estimates and longitudinal analyses of PT and LBW births in public facilities have not been comprehensively undertaken, nor has the relationship between their prevalence and associated neonatal health outcomes been systematically examined using national administrative data.

This study addresses that gap. Using data from India's Health Management Information System (HMIS) - covering over 29 million births across 700+ districts in two time periods, 2017–18 and 2022–23 - we present the first nationally representative, multi-period analysis of PT and LBW birth trends across India's public health system. We further examine district-level associations between neonatal vulnerability and a range of health outcomes, including caesarean section rates, breastfeeding initiation within one hour, SNCU admissions and mortality, and infant mortality across the early, late, and post-neonatal periods.

Materials and Methodology

Data Source

This study utilised data from the Health Management Information System (HMIS), a government-to-government (G2G) web-based monitoring platform established by the Ministry of Health and Family Welfare (MoHFW), Government of India. The HMIS monitors the National Health Mission (NHM) and allied health programmes across all public health facilities in all states and union territories, recording data for service delivery and infrastructure indicators.

District-level annual data were extracted for two time periods, 2017-18 and 2022-23. In 2017-18, data were available for 703 of 712 districts listed in the HMIS; by 2022-23, the total number of districts had increased to 784, of which 757 were included. Discrepancies in coverage across both periods reflect missing data for a subset of districts. All data were extracted from the HMIS portal as of April 22, 2024.

Study Variables

The following indicators were derived from extracted HMIS data:

Neonatal Vulnerability Indicators: Preterm births as a proportion of total live births; LBW newborns as a proportion of total live births.

Maternal Care Indicators: First-trimester ANC registrations as a proportion of total ANC registrations; four or more ANC checkups as a proportion of total ANC registrations.

Neonatal Health Outcomes: Caesarean section deliveries as a proportion of total institutional deliveries; newborns breastfed within one hour as a proportion of total live births; SNCU admissions as a proportion of total live births; SNCU deaths as a proportion of total SNCU admissions; and infant deaths per 1,000 live

births, disaggregated into early neonatal (within 24 hours), late neonatal (1-4 weeks), and post-neonatal (1-12 months) periods.

Statistical Analysis

Descriptive statistics were computed for all indicators across both time periods. To examine the geographic distribution of neonatal vulnerability, district-level PT and LBW birth rates were mapped using GeoDa software. Districts were categorised into three groups based on PT birth rates (less than 3%, 3-5%, and greater than 5% per 100 live births) and LBW birth rates (less than 10%, 10-15%, and greater than 15% per 100 live births). One-way Analysis of Variance (ANOVA) was used to test for statistically significant differences in mean values of maternal and neonatal health indicators across these district categories, separately for each time period.

To quantify the associations between neonatal vulnerability indicators and health outcomes, a series of simple linear regression models were estimated. To avoid multicollinearity and to estimate the separate bivariate association of each neonatal vulnerability indicator with each outcome, two separate models were run for each dependent variable:

Model 1: Dependent variable regressed on the district-level PT birth rate.
Model 2: Dependent variable regressed on the district-level LBW birth rate.

Each model was specified as:

$$Y_i = \beta_0 + \beta_1 X_{i1} + \epsilon_i$$

where Y_i is the dependent variable, β_0 is the intercept, β_1 is the regression coefficient for predictor X_{i1}, and ϵ_i is the error term. Results are reported as regression coefficients (B) with 95% confidence intervals and p-values. Statistical significance was set at p less than 0.05. All analyses were performed using Stata Version 16.

Results

Table 1 presents descriptive statistics for neonatal vulnerability, maternal care, and neonatal health outcome indicators across 703 and 757 districts for 2017-18 and 2022-23, respectively, derived from 15,482,897 and 13,896,279 live births reported from public health facilities across India.

PT birth rates increased from 3.9% (SD: 3.9) to 5.1% (SD: 4.0) over the five-year period. LBW rates similarly rose from 12.9% (SD: 6.3) to 14.7% (SD: 7.0). Among maternal care indicators, first-trimester ANC registrations increased from 64.4% to 80.4%, and the proportion of women completing four or more ANC checkups rose from 63.9% to 86.0%. Caesarean section deliveries as a proportion of total institutional deliveries increased from 12.7% to 16.6%.

Among neonatal health outcomes, the proportion of newborns breastfed within one hour of birth increased marginally from 92.7% to 94.2%. SNCU admissions as a proportion of total live births rose from 7.6% to 10.7%, while SNCU deaths as a proportion of total SNCU admissions declined from 7.2% to 6.2%. Early neonatal deaths per 1,000 live births declined from 3.0 to 2.0, while late neonatal deaths increased from 8.0 to 9.0, and post-neonatal deaths rose from 1.0 to 4.0. Overall infant deaths per 1,000 live births increased from 12.0 to 15.0 over the study period.

Table 1 Descriptive statistics of neonatal vulnerability, maternal care, and neonatal health outcomes in India, 2017-18 and 2022-23

Indicators	2017-18		2022-23	
	N	% (SD)	N	% (SD)
Neonatal Vulnerability				
Preterm births to total live births	703	3.9 (3.9)	757	5.1 (4.0)
Low birth-weight newborns to total live births	703	12.9 (6.3)	757	14.7 (7.0)
Maternal Care				
1st trimester ANC Registration to total ANC registrations	703	64.4 (19.4)	757	80.4 (16.4)
4+ ANC Checkups to total ANC registrations	703	63.9 (24.9)	757	86.0 (22.7)
C-section deliveries to total institutional deliveries	703	12.7 (14.9)	757	16.6 (17.0)
Neonatal health outcomes				
Newborns breastfed within 1 hour to total live births	703	92.7 (8.9)	757	94.2 (7.3)
SNCU admissions to total live births	703	7.6 (8.8)	757	10.7 (10.4)
SNCU Deaths to total SNCU admissions	616	7.2 (5.2)	680	6.2 (4.4)
Early neonatal deaths per 1000 live births (within 24 h.)	703	3.0 (3.4)	757	2.0 (2.8)
Late-neonatal deaths per 1000 live births (1-4 weeks)	703	8.0 (7.8)	757	9.0 (8.1)
Post-neonatal deaths per 1000 live births (1-12 months)	703	1.0 (2.3)	757	4.0 (5.8)
Infant deaths per 1000 live births	703	12.0 (11.5)	757	15.0 (14.1)

Table 2 presents state and union territory-level estimates and absolute changes in PT and LBW birth rates across both study periods.

In 2017-18, LBW rates ranged from 3.4% in Nagaland to 33.5% in DNHDD. By 2022-23, these ranged from 2.7% in Nagaland to 33.1% in DNHDD. In both periods, five states accounted for 55% of all LBW births nationally: Uttar Pradesh, West Bengal, Bihar, Madhya Pradesh, and Rajasthan, with Madhya Pradesh replacing Bihar in the 2022-23 grouping. Among larger states, the highest LBW rates in 2022-23 were recorded in West Bengal (24.6%), Odisha (21.3%), Gujarat (20.4%), Tamil Nadu (19.2%), and Maharashtra (18.6%).

Absolute changes in LBW rates over the five-year period ranged from a decrease of 2.9 percentage points in Tripura to an increase of 7.5 percentage points in Haryana. Of 36 states and UTs, 25 recorded an increase in LBW rates. Notable increases were observed in Delhi (6.4 pp), Haryana (7.5 pp), West Bengal (3.9 pp), Madhya Pradesh (3.9 pp), Chandigarh (3.5 pp), and Sikkim (3.2 pp). Seven states and UTs recorded a decline, with the notable increase in LBW rate by 1.8 percentage points overall.

PT birth rates in 2017-18 ranged from 0.4% in Manipur to 11.0% in Chandigarh. By 2022-23, these ranged from 1.5% in Bihar to 14.1% in DNHDD. Five states accounted for 55% of all PT births nationally in both periods: Uttar Pradesh, West Bengal, Madhya Pradesh, Maharashtra, and Bihar in 2017-18, with Rajasthan replacing Bihar by 2022-23.

Absolute changes in PT rates ranged from a decrease of 1.2 percentage points in both Puducherry and Lakshadweep to an increase of 8.1 percentage points in DNHDD. Among larger states, West Bengal recorded the greatest increase (5.8 pp), followed by Himachal Pradesh (4.5 pp), Gujarat (4.0 pp), Delhi (3.9 pp), Goa (3.9 pp), Punjab (3.8 pp), Kerala (3.1 pp), and Haryana (3.1 pp). Of 36

states and UTs, 26 recorded an increase in PT rates, while decreases were observed in Bihar, Uttar Pradesh, Tripura, Uttarakhand, Telangana, Puducherry, and Lakshadweep. The national PT rate increased by 1.2 percentage points. Overall, twenty-one states and UTs recorded concurrent increases in both LBW and PT rates over the study period.

Table 2 Levels and trends in low birth-weight and preterm births by states and UTs in India, 2017-18 and 2022-23

States/UTs	Low birth-weight newborns to total live births (%)			Preterm births to total live births (%)		
	2017-18	2022-23	Δ(pp)	2017-18	2022-23	Δ(pp)
A&N Islands#	16.0	16.9	0.9	9.1	10.7	1.6
Andhra Pradesh	10.0	9.9	-0.1	3.4	4.9	1.5
Arunachal Pradesh	6.3	6.0	-0.3	2.6	3.1	0.5
Assam	14.8	14.2	-0.6	3.3	5.9	2.6
Bihar	8.9	10.1	1.2	1.8	1.5	-0.3
Chandigarh	20.9	24.4	3.5	11.0	11.0	0
Chhattisgarh	10.7	13.3	2.6	4.7	5.4	0.7
Delhi	19.4	25.8	6.4	5.9	9.8	3.9
Goa	23.9	25.0	1.1	10.8	14.7	3.9
Gujarat	19.1	20.4	1.3	4.9	8.9	4
Haryana	8.6	16.1	7.5	5.3	8.4	3.1
Himachal Pradesh	13.0	15.8	2.8	3.6	8.1	4.5
J&K#	5.3	5.3	0	1.9	3.9	2
Jharkhand	7.6	7.8	0.2	2.2	2.2	0
Karnataka	12.1	13.2	1.1	4.9	5.1	0.2
Kerala	14.4	16.5	2.1	2.8	5.9	3.1
Ladakh	-	9.4	-	-	6.7	-
Lakshadweep	7.4	5.1	-2.3	3.2	2.0	-1.2
Madhya Pradesh	14.2	18.1	3.9	4.9	7.1	2.2
Maharashtra	16.2	18.6	2.4	5.2	5.8	0.6
Manipur	4.4	3.9	-0.5	0.4	1.1	0.7
Meghalaya	6.6	8.1	1.5	1.6	2.9	1.3
Mizoram	4.3	5.3	1	0.7	2.9	2.2
Nagaland	3.4	2.7	-0.7	1.2	1.5	0.3
Odisha	19.0	21.3	2.3	6.0	7.0	1
Puducherry	15.1	15.1	0	8.1	6.9	-1.2
Punjab	12.7	14.3	1.6	7.2	11.0	3.8
Rajasthan	14.6	15.8	1.2	2.2	4.6	2.4
Sikkim	4.7	7.9	3.2	0.9	2.3	1.4
Tamil Nadu	18.6	19.2	0.6	3.6	4.6	1
Telangana	9.6	10.4	0.8	3.8	3.1	-0.7
DDNH&DD*#	33.5	33.1	-0.4	6.0	14.1	8.1
Tripura	13.3	10.4	-2.9	3.4	3.0	-0.4
Uttar Pradesh	10.2	11.8	1.6	3.8	3.4	-0.4
Uttarakhand	8.9	9.0	0.1	2.7	2.2	-0.5
West Bengal	20.7	24.6	3.9	6.5	12.3	5.8
Total	**12.9**	**14.7**	**1.8**	**3.9**	**5.1**	1.2

 # : A&N Islands: Andaman and Nicobar Islands, DDNH&DD: The Dadra and Nagar Havel & Daman and Diu

**: To facilitate comparison, the individual values for Dadra and Nagar Haveli, and Daman and Diu – which were separate Union Territories in 2017-18 – have been combined. These territories were merged to form a single Union Territory (DNHDD) in 2020.*

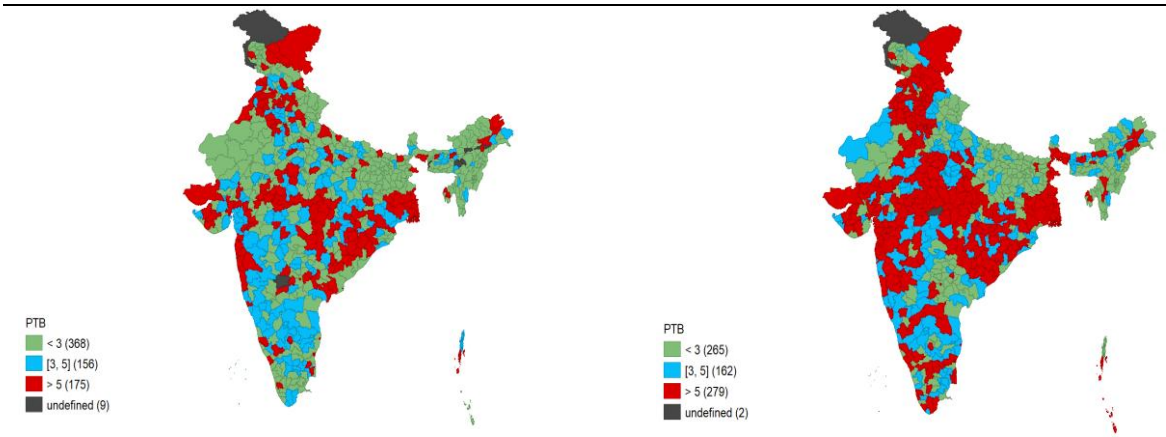
Figure 1 presents district-level maps of PT and LBW birth rates for both study periods. In 2017-18, 53% of districts reported PT birth rates below 3 per 100 live births, 22% fell in the 3-5 range, and 25% reported rates above 5. By 2022-23, the proportion of districts with PT rates below 3 declined to 39%, while those with rates above 5 increased to 38%. For LBW, 39% of districts reported rates below 10 per 100 live births in 2017-18, 29% fell in the 10-15 range, and 32% reported rates above 15. By 2022-23, districts with LBW rates above 15 increased to 39%, while those below 10 declined to 34%.

At the state level, West Bengal recorded the highest proportion of high-burden districts for both indicators, with all districts classified as high-burden for PT births by 2022-23, up from 61% in 2017-18, and 96% classified as high-burden for LBW, up from 91%. Substantial increases in high-burden district proportions were also recorded in Haryana, Himachal Pradesh, and Chhattisgarh for PT births, and in Madhya Pradesh, Maharashtra, and Haryana for LBW. Regionally, the maps indicate a concentration of increasing vulnerability in the central and eastern parts of India.

Figure 1 District-Level Distribution of Neonatal Vulnerability in India: Preterm Births (A) and Low Birth-Weight Neonates (B), 2017-18 and 2022-23

A. Preterm births to total live births (per 100)

2017-18 2022-23



B. Low birth-weight neonates to total live births (per 100)

2017-18 2022-23

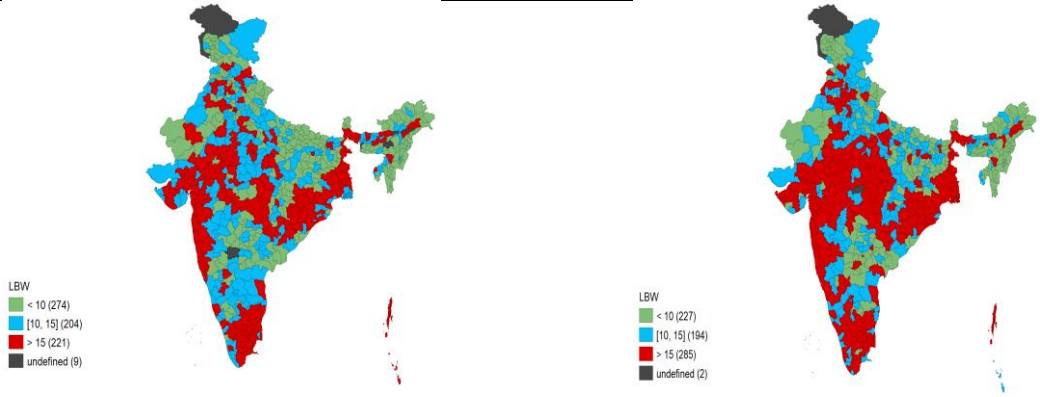


Table 3 Comparison of Means for Maternal and Neonatal Health Indicators by Preterm Birth Rates in India: ANOVA Results, 2017-18 and 2022-23

Indicators (mean in %)		Preterm births (per 100 live births)			
		<3	3-5	>5	Total
1st trimester ANC Registration to total ANC registrations	2017-18*	64.5	73.7	71.4	68.3
	2022-23*	75.8	83.5	84.7	81.1
4+ ANC Checkups to total ANC registrations	2017-18*	59.8	73.6	73.4	66.3
	2022-23*	76.8	88.2	87.7	83.6
C-section deliveries to total institutional deliveries	2017-18*	13.1	15.1	16.6	14.5
	2022-23*	17.3	20.2	21.2	19.4
Newborns breastfed within 1 hour to total live births	2017-18*	92.9	92.8	90.9	92.3
	2022-23*	94.4	93.8	93.2	93.8
SNCU admissions to total live births	2017-18*	6.8	8.6	11.2	8.4
	2022-23*	8.5	11.8	15.7	12.1
SNCU Deaths to total SNCU admissions	2017-18*	4.8	5.2	6.6	5.4
	2022-23*	3.9	4.6	5.7	4.8
Early neonatal deaths per 1000 live births (within 24 h.)	2017-18*	2.0	4.0	5.0	3.0
	2022-23*	1.0	2.0	3.0	2.0
Late-neonatal deaths per 1000 live births (1-4 weeks)	2017-18*	5.0	10.0	11.0	7.0
	2022-23*	4.0	8.0	12.0	8.0
Post-neonatal deaths per 1000 live births (1-12 months)	2017-18*	1.0	2.0	2.0	2.0
	2022-23*	3.0	5.0	7.0	5.0
Infant deaths per 1000 live births	2017-18*	9.0	15.0	17.0	13.0
	2022-23*	9.0	15.0	22.0	15.0

**: p-value<0.05*

Table 3 presents mean values of maternal and neonatal health indicators across districts categorised by PT birth rate, along with ANOVA test results, for both study periods.

Districts with PT rates above 5 per 100 live births reported higher mean values for first-trimester ANC registration (71.4% in 2017-18; 84.7% in 2022-23) and four or more ANC checkups (73.4% in 2017-18; 87.7% in 2022-23) compared to low-burden districts (below 3 per 100 live births), which recorded means of 64.5% and 73.7% for the same indicators in 2017-18, and 75.8% and 83.5% in 2022-23. Caesarean section rates were highest in high-burden districts in both periods (16.6% and 21.2%), compared to low-burden districts (13.1% and 17.3%).

SNCU admissions were highest in high-burden districts (11.2% in 2017-18; 15.7% in 2022-23) and lowest in low-burden districts (6.8% in 2017-18; 8.5% in 2022-23). Mean SNCU death rates were also highest in high-burden districts in both periods, though rates declined across all categories between 2017-18 and 2022-23. The proportion of newborns breastfed within one hour was lowest in high-burden districts (90.9% in 2017-18; 93.2% in 2022-23) compared to low-burden districts (92.9% in 2017-18; 94.4% in 2022-23).

Mean infant deaths per 1,000 live births in districts with PT rates above 5 were 17 and 22 in 2017-18 and 2022-23, respectively, compared to 9 in both periods for districts with PT rates below 3. Differences across early, late, and post-neonatal death rates were also

consistently higher in high-burden districts. All differences in means were statistically significant at p less than 0.05.

Table 4 presents the equivalent ANOVA results for districts categorised by LBW rate. Patterns were consistent with those observed for PT birth rate categories.

Table 4 Comparison of Means for Maternal and Neonatal Health Indicators by Low Birth-weight Rates in India: ANOVA Results, 2017-18 and 2022-23

Indicators (mean)		Low birth-weight births (per 100 live births)			
		<10	10-15	>15	Total
1st trimester ANC Registration to total ANC registrations	2017-18*	60.9	70.0	75.9	68.3
	2022-23*	74.0	82.9	85.8	81.0
4+ ANC Checkups to total ANC registrations	2017-18*	57.5	69.3	74.4	66.3
	2022-23*	73.4	88.9	88.8	83.6
C-section deliveries to total institutional deliveries	2017-18*	11.2	14.6	18.4	14.4
	2022-23*	17.7	17.4	22.5	19.4
Newborns breastfed within 1 hour to total live births	2017-18*	93.5	92.6	90.7	92.4
	2022-23*	94.3	94.2	93.2	93.9
SNCU admissions to total live births	2017-18*	5.3	8.0	12.4	8.4
	2022-23*	7.9	10.9	16.3	12.0
SNCU Deaths to total SNCU admissions	2017-18*	3.9	5.3	6.9	5.4
	2022-23*	4.0	3.9	6.1	4.9
Early neonatal deaths per 1000 live births (within 24 h.)	2017-18*	2.0	3.0	4.0	3.0
	2022-23*	2.0	2.0	3.0	2.0
Late-neonatal deaths per 1000 live births (1-4 weeks)	2017-18*	5.0	8.0	12.0	8.0
	2022-23*	4.0	7.0	12.0	8.0
Post-neonatal deaths per 1000 live births (1-12 months)	2017-18*	1.0	1.0	2.0	1.0
	2022-23*	4.0	5.0	6.0	5.0
Infant deaths per 1000 live births	2017-18*	8.0	12.0	19.0	13.0
	2022-23*	10.0	15.0	21.0	16.0

**: p-value<0.05*

High-burden districts (LBW above 15 per 100 live births) reported higher mean values for ANC indicators, caesarean section rates, SNCU admissions and mortality, and infant deaths across all periods, compared to low-burden districts (LBW below 10 per 100 live births). Mean rates of newborns breastfed within one hour declined from 93.5% in low-burden to 90.7% in high-burden districts in 2017-18, with a narrower differential of 94.3% to 93.2% in 2022-23. Mean infant deaths per 1,000 live births were 8 and 19 in low- and high-burden districts respectively in 2017-18, and 10 and 21 in 2022-23. All differences in means were statistically significant at p less than 0.05.

Figure 2 presents a scatter plot matrix illustrating correlations between maternal and neonatal health indicators at the district level for both study periods. PT and LBW birth rates showed positive correlations with SNCU admissions, SNCU deaths, caesarean section rates, and infant deaths across all three mortality periods. Both indicators showed negative correlations with the proportion of newborns breastfed within one hour.

Figure 2 Scatter Plot Matrix of Maternal and Neonatal Health Indicators in India, 2017-18 and 2022-23

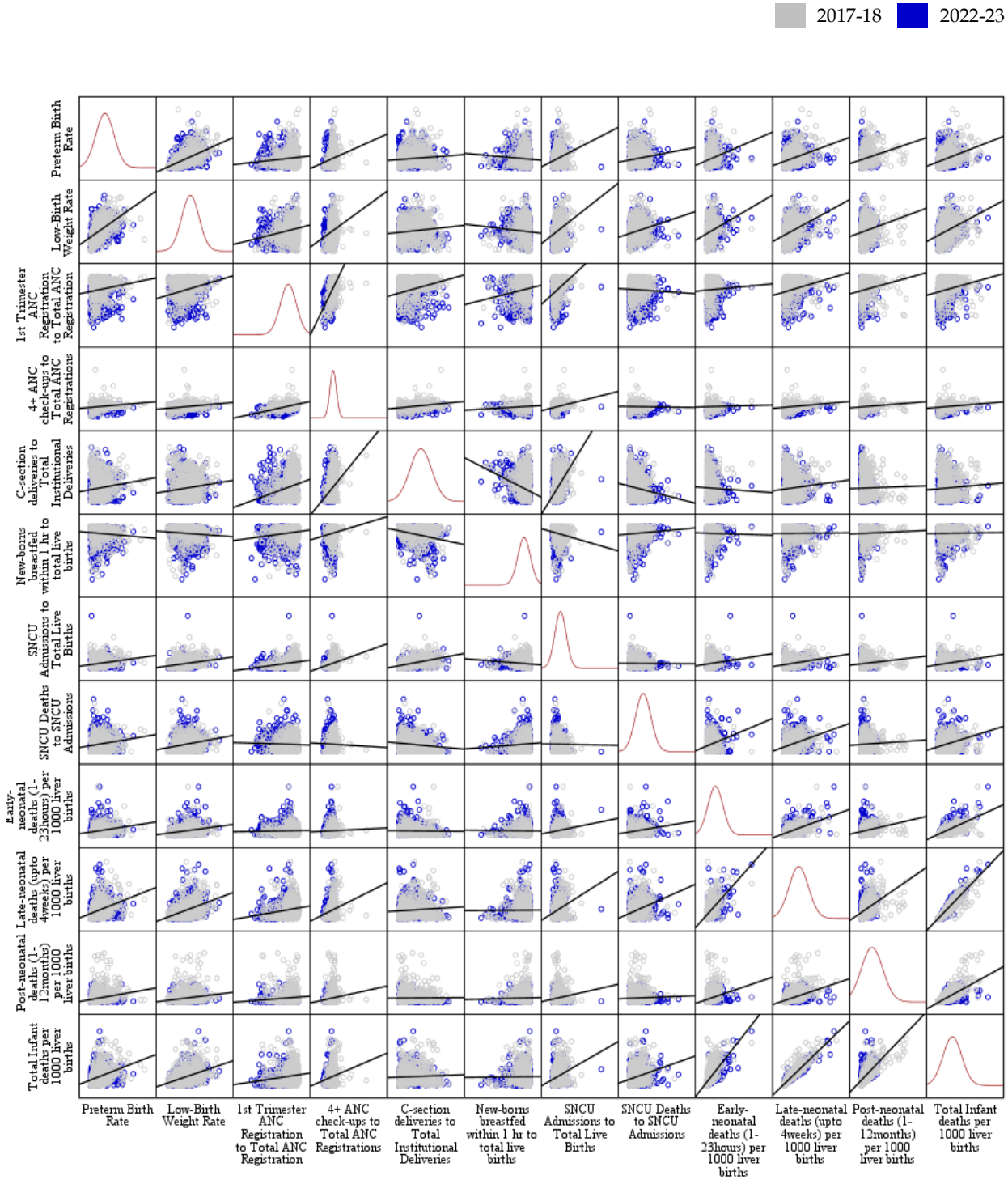


Table 5 Regression Analysis of Neonatal Health Outcomes with Individual Predictors: Preterm Births and Low Birth-Weight Rates, 2017-18 and 2022-23

2017-18		
	Predictors	
Dependent variables	Preterm births to total live births	Low birth-weight newborns to total live births
C-section deliveries to total institutional deliveries	0.211 (-0.067 - 0.489)	0.461 (0.290 - 0.632)***
Newborns breastfed within 1 hr. to total live births	-0.200 (-0.366 - -0.034)*	-0.153 (-0.257 - -0.050)*
SNCU admissions to total live births	0.345 (0.182 - 0.508)***	0.468 (0.390 - 0.583)***
SNCU Deaths to total SNCU admissions	0.199 (0.083 - 0.314)**	0.217 (0.152 - 0.283)***
Early-neonatal deaths per 1000 live births (<24 hrs.)	0.158 (0.095 - 0.220)***	0.170 (0.132 – 0.208)***
Late-neonatal deaths per 1000 live births (1-4 weeks)	0.438 (0.296 – 0.580)***	0.524 (0.441 – 0.607)***
Post-neonatal deaths per 1000 live births (1-12 months)	0.023 (-0.020 – 0.066)	0.034 (0.007 – 0.061)**
Infant deaths per 1000 live births	0.619 (0.409 – 0.829)***	0.728 (0.605 – 0.851)***

2022-23		
	Predictors	
Dependent variables	Preterm births to total live births	Low birth-weight newborns to total live births
C-section deliveries to total institutional deliveries	0.588 (0.292 - 0.883)***	0.366 (0.194 - 0.537)***
Newborns breastfed within 1 hr. to total live births	-0.150 (-0.278 - 0.021) *	-0.068 (-0.142 - 0.007)
SNCU admissions to total live births	0.847 (0.675 - 1.020) ***	0.589 (0.483 - 0.686)***
SNCU Deaths to total SNCU admissions	0.237 (0.156 - 0.317)***	0.146 (0.097 - 0.195)***
Early-neonatal deaths per 1000 live births (<24 hrs.)	0.218 (0.172 - 0.265)***	0.096 (0.069 - 0.124)***
Late-neonatal deaths per 1000 live births (1-4 weeks)	0.916 (0.790 – 1.043)***	0.519 (0.445 – 0.592)***
Post-neonatal deaths per 1000 live births (1-12 months)	0.335 (0.237 – 0.434)***	0.156 (0.099 – 0.214)***
Infant deaths per 1000 live births	1.470 (1.247 – 1.693)***	0.772 (0.640 – 0.903)***
** : p-value < 0.05, ** : p-value < 0.01, *** : p-value < 0.001*		

Table 5 presents regression coefficients from simple linear regression models for each dependent variable, with PT and LBW rates as separate predictors, for both study periods.

In 2017-18, a one percentage point increase in the district-level PT birth rate was associated with increases of 0.158 per 1,000 live births in early neonatal deaths (95% CI: 0.095-0.220), 0.438 in late neonatal deaths (95% CI: 0.296-0.580), 0.023 in post-neonatal deaths (95% CI: -0.020-0.066), and 0.619 in total infant deaths (95% CI: 0.409-0.829). A one percentage point increase in LBW rate was associated with increases of 0.170 in early neonatal deaths (95% CI: 0.132-0.208), 0.524 in late neonatal deaths (95% CI: 0.441-0.607), 0.034 in post-neonatal deaths (95% CI: 0.007-0.061), and 0.728 in total infant deaths (95% CI: 0.605-0.851).

By 2022-23, the association between PT birth rate and late neonatal deaths increased to 0.916 (95% CI: 0.790-1.043), and with total infant deaths to 1.470 (95% CI: 1.247-1.693). For LBW, the association with late neonatal deaths remained comparable at 0.519 (95% CI: 0.445-0.592), while the association with total infant deaths was 0.772 (95% CI: 0.640-0.903). The association between PT birth rate and SNCU admissions strengthened from 0.345 (95% CI: 0.182-0.508) in 2017-18 to 0.847 (95% CI: 0.675-1.020) in 2022-23. The negative association between PT birth rate and breastfeeding within one hour was statistically significant in both periods (-0.200 in 2017-18; -0.150 in 2022-23), while for LBW this association was significant in 2017-18 (-0.153) but not in 2022-23 (-0.068). All other associations were statistically significant at p less than 0.05 unless otherwise indicated in Table 5.

Discussion

India integrated the Every Newborn Action Plan into its national policy framework through the India Newborn Action Plan in 2014, yet national estimates on PT births were only incorporated into the HMIS portal from 2017-18 onwards (Mason et al., 2014). This study represents the first nationally representative, multi-period ecological analysis of PT and LBW birth trends and their associations with neonatal health outcomes at the district level in India, and the findings are unambiguous: neonatal vulnerability in India's public health system is worsening, geographically concentrated, and systematically associated with worse outcomes across every metric examined.

The upward trajectory of both PT and LBW rates across the majority of states and UTs is consistent with global evidence that these indicators in LMICs have remained stagnant or deteriorated over the past decade, particularly across South Asia (Okwaraji et al., 2024; Ohuma et al., 2023; Smid et al., 2016). Critically, India's burden cannot be attributed to population size alone. The distinction between states that contribute disproportionately through sheer birth volume and those that carry the highest rates reflects qualitatively different failures in health system performance. When a state reports uniformly high-burden districts across both indicators, as West Bengal does by 2022-23, this signals a systemic breakdown in the quality and reach of maternal and newborn care that demands a different programmatic response than managing absolute numbers in a high-fertility state (WHO, 2022). Conflating these two phenomena in resource allocation decisions risks misdirecting both attention and investment.

The geographic concentration of rising vulnerability in central and eastern India

reflects a convergence of challenged health systems, persistent maternal undernutrition, and constrained facility readiness (WHO, 2022). That meaningful reductions were observed in several states across both indicators is an important counterpoint: it demonstrates that the trend is not inevitable, and that targeted system strengthening produces measurable results. These states warrant systematic documentation as implementation models.

Perhaps the most policy-significant finding is the ANC paradox. High-burden districts report the highest ANC coverage, yet carry the worst neonatal outcomes. This decoupling of coverage from impact reflects a well-documented gap between the numerical completion of ANC visits and the quality of care delivered within them. Reducing neonatal vulnerability requires not more visits but better ones, specifically through integration of pre-conception and antenatal nutrition (WHO, 2022), structured fetal surveillance (Erkamp et al., 2020), and risk-stratified counselling (North et al., 2022). The programmatic implication is that indicator targets focused on visit counts are inadequate and potentially misleading.

The positive association between caesarean section rates and neonatal vulnerability operates through two concurrent pathways: clinically indicated intervention in response to fetal compromise, and non-medically indicated delivery independently contributing to PT and LBW outcomes (Silva et al., 2001; Zhang et al., 2019). The observation that caesarean rate increases were sharpest in lower-burden districts, where clinical justification is least evident, is concerning and points to a need for systematic audit and accountability mechanisms to curb unjustified surgical delivery.

The inverse relationship between neonatal vulnerability and early breastfeeding initiation is clinically expected, given the physiological and logistical barriers PT and LBW neonates face at birth. That PT birth rate remained a significant negative predictor of breastfeeding initiation across both periods underscores the importance of alternative feeding pathways. Evidence consistently supports the benefits of donor human milk for growth, immune function, and survival in this population (Kuschel & Harding, 2004; Suganuma et al., 2021), and its provision through an expanded CLMC network in high-burden districts must be treated as a clinical rather than ancillary service.

Declining SNCU case fatality rates across all district categories signal genuine improvement in the quality of acute newborn care, consistent with expanded SNCU capacity under NHM (Sinha et al., 2019). This is encouraging. However, the dissociation between improving inpatient survival and worsening late and post-neonatal mortality in high-burden districts reveals a structural gap that facility-based improvements at the point of birth cannot address alone. PT and LBW neonates face elevated post-discharge risks from immune compromise (Melville & Moss, 2013), nutritional vulnerability (Park et al., 2015), and fragmented follow-up that persist well into the first year of life. The strengthening association between neonatal vulnerability and infant mortality across the study period, driven predominantly by late and post-neonatal deaths, indicates a

reconfiguration of mortality risk: survival to discharge is improving, but survival through the first year is not keeping pace. A continuum-of-care framework that extends structured follow-up, nutritional surveillance, and family support well beyond hospital discharge is not optional in this context but a clinical and programmatic necessity (Melville & Moss, 2013; Park et al., 2015; Lipner & Huron, 2018).

This study's reliance on HMIS data introduces important limitations. Public facility births represent a declining share of total deliveries in many states, introducing selection bias that may inflate vulnerability estimates relative to the general population. Simultaneously, under-reporting in weaker health systems likely underestimates the true burden in the most vulnerable districts. The ecological design precludes causal inference, and district-level associations cannot be transposed to individual-level relationships without risk of ecological fallacy. Future research should prioritise longitudinal, individual-level data linkage across both public and private sectors.

Conclusion

This study presents the first nationally representative, multi-period ecological analysis of neonatal vulnerability across India's public health system, and its findings are concerning. PT and LBW birth rates have risen nationally, high-burden districts have multiplied, and health consequences are systematically worse in districts carrying the greatest burden across every outcome examined.

Two findings demand particular policy attention. First, the distinction between states that contribute disproportionately by birth volume and those carrying the highest rates reflects fundamentally different health system failures requiring different programmatic responses. Conflating them in resource allocation will misdirect investment. Second, improvements in acute newborn care, while genuine, have not been matched by reductions in late and post-neonatal mortality. The structural gap in the continuum of care after hospital discharge remains the most consequential unresolved challenge for PT and LBW neonates in India.

Addressing this requires, at minimum: routine recording of gestational age and birth weight across all facilities; ANC strengthened in content rather than coverage alone; accountability mechanisms for non-medically indicated caesarean delivery; expanded donor human milk access through CLMCs in high-burden districts; and SNCU growth matched by equal investment in post-discharge follow-up.

Reducing neonatal vulnerability in India is inseparable from the country's commitments under SDG target 3.2, the Global Nutrition Targets, and the National Health Mission. Current trajectories are moving in the wrong direction. Reversing them requires coordinated, evidence-driven action directed with precision at the districts and states where the burden is greatest and the gaps in care most consequential.

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