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RESEARCH

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Risk factors for preterm birth and its effect on neonatal mortality in India: evidence from the National Health Family Survey-5

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Abstract

Objectives Worldwide, preterm birth is a major contributor to under-five mortality and neonatal mortality. This study aimed to determine the patterns, and sub-national variations of preterm birth in India and identify factors associated with it. Additionally, the association of preterm birth with neonatal mortality was also explored.

Methods This study used data from the fifth round of the National Family Health Survey (NFHS-5) conducted during 2019–21. Bivariate analysis and complementary log-log discrete time hazard model were used to achieve the study objectives.

Results The prevalence of preterm births in India has dramatically increased over the years, with huge variations among the states. Younger and older maternal age (< 19 years and > 35years), poor economic status, birth intervals < 24 months, delivery by Caesarean section, inadequate antenatal care, residence in the central and northern regions of the country were associated with a higher likelihood of experiencing preterm births. Preterm births were associated with a notably high risk of neonatal mortality when compared to full-term births after adjusting effect of other socioeconomic and program-related factors. The risk of neonatal deaths was 20% higher among male child than females (OR = 1.20, 1.08–1.33), shorter mother height, mothers who smokes (OR = 1.27, 1.04–1.56) and births delivered through C section (OR = 1.31, 1.15–1.50).

Conclusions Preterm birth is a matter of major concern to policy makers as it contributes significantly to neonatal mortality. India urgently needs to accelerate investment in, and scale up primary interventions that prevent preterm births for achieving target 3.2 of the Sustainable Development Goals (SDGs) 2030.

Keywords Preterm birth, Neonatal mortality, Discrete hazard model, NFHS-5, India

1 Introduction

Globally, about 15 million preterm births occur annually. Despite advances in the medical field, the rate of preterm births has been rising across countries [1]. Preterm birth is the single largest contributory factor to under-five mortality and a significant contributor to neonatal mortality [2]. Of the 3.1 million neonatal deaths that occur in low- and middle-income countries every year, 35% are due to preterm birth and its associated complications [3].

The estimated global rate of preterm birth rate is 10.6% [4], with variations across countries ranging from 5–18% [2]. Sub-Saharan Africa and South Asia together account for 65% of total preterm births globally in 2020 [5]. The top five low- and middle -income countries contributing to preterm birth are India, China, Nigeria, Bangladesh, and Indonesia [1]with India having preterm birth rate of around 12% leading the list by contributing over 23% of all preterm births across the world. India accounts for the highest number of preterm births globally, with an estimated 3.5 million cases annually [6]. Preterm birth complications are among the leading causes of neonatal mortality [7]. According to the Sample Registration System (SRS) 2020, neonatal mortality in India stands at 20 per 1,000 live births, with substantial regional variations. Despite improvements in maternal health services, issues such as late or inadequate antenatal care, anaemia, and maternal malnutrition continue to contribute to poor birth outcomes [8].

Preterm birth rates and survival rates are significantly different across countries. Low-income countries have one in two infants die before 32 weeks gestation, while most infant survive in high-income countries. Extreme preterm births are particularly concerning, with 9 in 10 mortality in low-income countries [9]. Infants born prematurely had a fourfold higher likelihood of mortality during the early neonatal or late neonatal periods and more than 1.7 times higher risk of postneonatal mortality in India [10].

In addition to being at a significant risk of neonatal and under-five child mortality, preterm infants that survive are at an increased risk of early and late morbidities. Early morbidities include respiratory distress syndrome, chronic lung disease, infections, intraventricular haemorrhage, and temperature instability [11]whereas late morbidities include neurodevelopmental delay, stunted growth, hypertension, and cardiovascular diseases [12, 13].

Thus, preterm birth is a global health problem and a major challenge to policy makers across countries, especially those like India that experience high preterm birth rates, with resultant high neonatal and under-five mortality rates. In India, preterm birth remains a leading cause of neonatal deaths, contributing to nearly one-third of all neonatal mortality [6, 7]. Despite policy efforts like the India Newborn Action Plan and increased institutional deliveries, the prevalence of preterm births remains persistently high, with considerable regional variation and disparities by socioeconomic status. Previous research show that risk of preterm birth was significantly higher among women in the richest wealth quintile [14]. Understanding the predictors and consequences of preterm births within the Indian context is critical for achieving national targets on neonatal and under-five mortality reduction under the Sustainable Development Goals (SDGs). Paying attention to this problem assumes importance especially as three of every four preterm infant deaths are avoidable and the long-term health outcomes among babies that survive can be improved by scaling up low-cost interventions available in many low- and middle-income settings [15].

Prior Indian studies have examined specific determinants of preterm birth [1]but there is limited evidence exploring its link to neonatal mortality using large-scale, nationally representative data. Our study therefore aims to determine the trends and patterns of preterm birth in India and its sub-national variations and to identify possible contributing factors associated with it. In addition, we attempt to analyse the association of preterm birth with neonatal mortality and suggest policy recommendations to minimise it. To better understand temporal changes and the current burden of neonatal mortality and preterm births in India, it is useful to compare findings from the latest NFHS-5 (2019–21) with previous rounds of the NFHS. This allows for an assessment of progress and persisting gaps in maternal and child health outcomes over time.

2 Methods

2.1 Data sources: sample size and design

This study used data from the fifth round of the National Family Health Survey (NFHS-5), which was a nationwide survey conducted in India during 2019–21 by the International Institute for Population Sciences (IIPS), Mumbai under the stewardship of Ministry of Health and Family Welfare, Govt. of India. The survey provides district-level estimates for many vital health and nutrition indicators for each state and Union Territories (UTs) of India. A total of 724,115 women and 101,839 men from 636,699 households were interviewed. For our study, we used reproductive calendar data to calculate preterm birth. The reproductive calendar contains a monthly history of birth events such as births, pregnancies, pregnancy terminations, the use of contraceptives, and the reasons for stopping the use of contraception etc. for a period of 80 months before the survey month. To reduce self-reporting inaccuracies, we only took into account reproductive histories spanning five years, or up to 59 months. A total of 232,920 live births had occurred during five years before the survey, out of which 176,843 were the last births. After removing missing information on maternal characteristics and incomplete child information, the analytical sample was reduced to 164,825 births. More details on sampling and data can be found from NFHS-5 report [8]. Figure 1 shows the flowchart the sample selection for the analysis.

To contextualize the findings from NFHS-5, selected indicators related to neonatal mortality and preterm birth were compared with data from NFHS-1 to NFHS-4. Data from NFHS Factsheets and national reports were compiled to assess historical trends. This secondary data analysis was descriptive and aimed to supplement the findings from NFHS-5 by illustrating long-term shifts in outcomes.

2.2 Study variables

2.2.1 Outcome variable

The outcome variables for the study were preterm birth and neonatal death. The World Health Organization defines preterm birth as a live birth before 37 weeks of gestation [2]. On the other hand, neonatal death is defined as the death of a baby within the first 28 days of life. We calculated preterm births from the information on the duration of pregnancy (months of gestation) using reproductive calendar. Owing to the data availability, a birth was termed as preterm when the birth occurred before 9 completed months of pregnancy, otherwise it was considered a full term birth [16] in all three NFHS rounds (3, 4, and 5). The criteria used for classification of a birth as preterm or full birth in this study differs from the standard WHO definition (< 37 weeks).

2.2.2 Explanatory variables

Socioeconomic variables used in this study were: wealth index of household (poorest, poorer, middle, richer, richest), educational status of mother (no formal education,

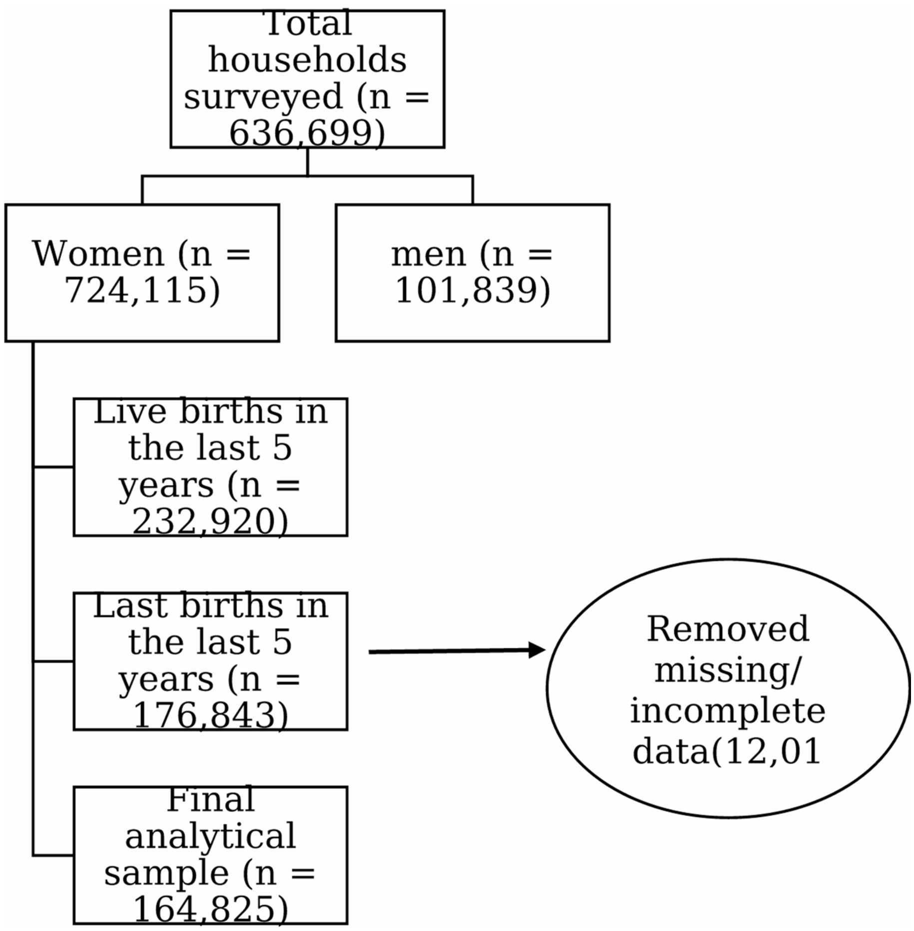

Fig. 1 Flowchart for sample selection process

primary, secondary, higher), caste (Scheduled Caste (SC), Scheduled Tribe (ST), Other backward class (OBC), others), religion (Hindu, Muslim, others), place of residence (rural, urban), and region of residence (North, Central, East, North-East, West, South).

Age at delivery (< 19 years, 20–24 years, 25–29 years, 30–34 years, 35 + years), preterm birth (recorded as preterm if the birth occurred before nine months), delivery by C-section (no, yes), ANC visits (no ANC, any ANC), intake of iron and folic acid tablets (IFA) during pregnancy (no, yes), number of TT injections (no, one, two or more), birth interval (First Birth, < 24 months, 24–48 months and > 48 months), mother's height (< 145 cm, 145–149 cm, 150–154 cm, > 155 cm), alcohol consumption (no, yes), smoking (no, yes), birth time (before COVID-19, post COVID-19 onset) and child sex (male, female) were also used as predictor variables in our analysis. Respondents were asked the number of ANC visits. It the response was zero it was recoded as 'no ANC' visit and otherwise 'any ANC' visit. The birth time was calculated on the basis of date of birth. If it took place before the nationwide lockdown (i.e., 25th March,2020) then the birth was consider as before COVID-19 birth and if it took place on/after 25th March,2020 then birth was considered as post-COVID-19 onset. Figure 2 shows the conceptual framework associated with preterm birth and neonatal mortality.

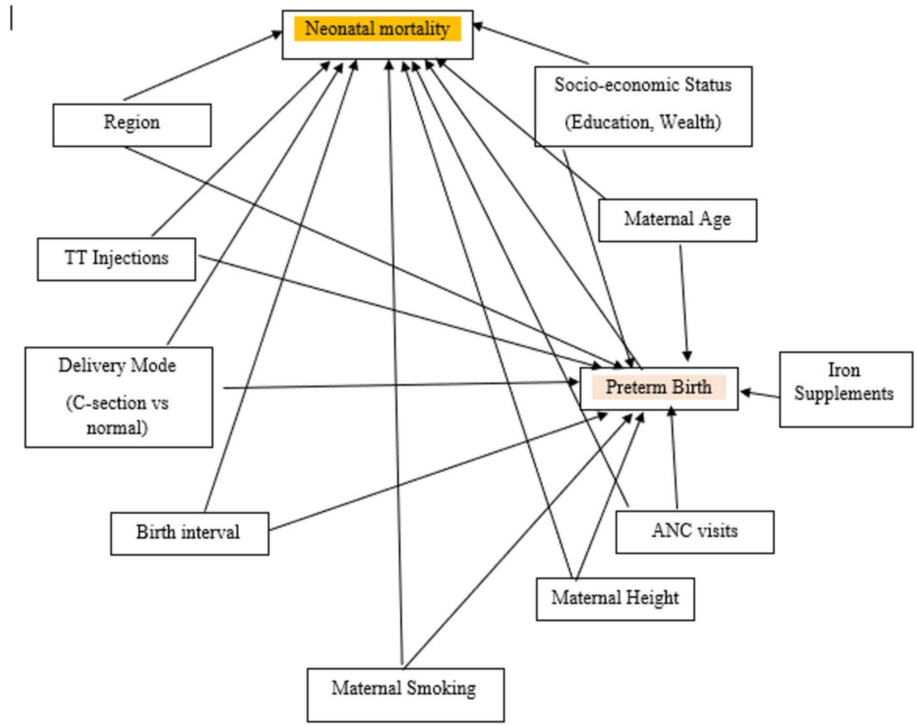

Fig. 2 Conceptual framework: preterm birth and neonatal mortality

2.3 Statistical analysis

Descriptive statistics were computed to understand the distribution of the study population according to various socioeconomic and demographic characteristics. We used bivariate analysis to understand the prevalence of preterm births by various socioeconomic and demographic characteristics and used complementary log-log discrete time hazard model to adjust unobserved maternal level heterogeneity. This model is helpful to estimate the extent of association between the adverse effect of preterm birth on neonatal death after adjusting for various other socioeconomic and demographic variables. To address complex survey design, appropriate adjustment were implemented which included adjustment for clustering and stratum effect in survey weight [8]. Sampling weights, clustering, and stratification were adjusted using svyset commands to ensure population-representative estimates and correct standard errors in the complementary log-log hazard models. To estimate the possibility of reducing neonatal deaths among children as a proportion of total preterm births, we calculated the Population Attributable Risk (PAF). Unadjusted and adjusted effect of preterm birth and various socio-economic factors on neonatal mortality in India using logistic regression analysis were also calculated. Data analysis was conducted using STATA version 16.

2.4 Ethical statement

Data used for this study are obtained from the National Family Health Survey-5 (2019–2021). Information is openly accessible and in the public domain (http://rchiips.org/nfhs/districtfactsheet_NFHS-5.shtml). As the NFHS adhered to ethical clearance standards and procedures, no additional ethics statement or consent for publishing was needed for this investigation.

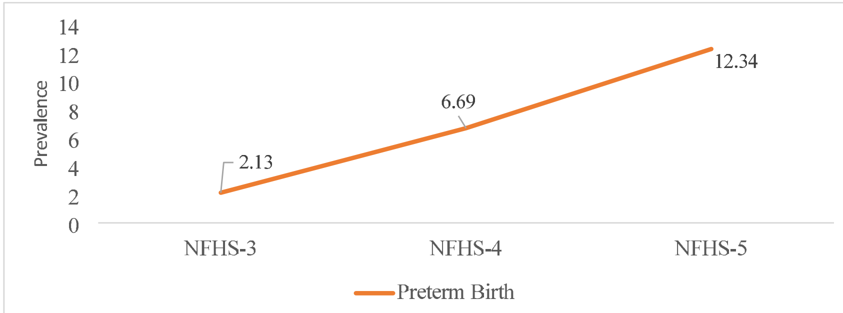

Fig. 3 Trends in the prevalence of preterm births across NFHS-3 (2005-06), NFHS-4 (2015–16) and NFHS-5 (2019–21) survey in India. Preterm birth was defined as < 9 completed months of gestation, as reported in NFHS. Gestational age was recorded in months, not weeks, in all three survey rounds

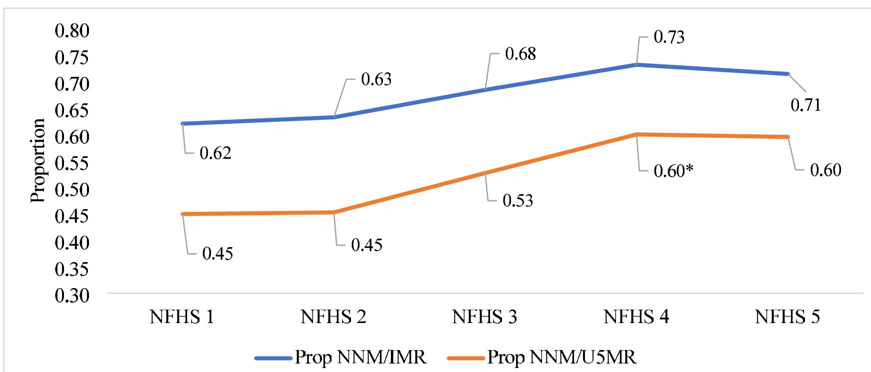

Fig. 4 Trends in the proportion of neonatal mortality to infant mortality and the proportion of neonatal mortality to under five mortality in India across five rounds of the NFHS Survey, India. *Indicates being significant at 10%. NNM/IMR indicates the proportion of neo-natal mortality to infant mortality. NNM/U5MR indicates the proportion of neonatal mortality (NNM) to under -five mortality (U5MR). NFHS-1 (1992–93), NFHS-2 (1998–99), NFHS-3 (2005–06), NFHS-4 (2015–16), and NFHS-5 (2019–21)

3 Results

There was a six-fold increase in the prevalence of preterm birth from 2005-06 (2.1%) to 2019-21 (12.34%) (Fig. 3). Although there was a decline in the prevalence of neonatal, infant, and under-five mortality over time, the proportion of neonatal mortality to under-five mortality witnessed significant increase from NFHS-1 to NFHS-4 (Fig. 4). Figure 5 shows the state-wise prevalence of preterm births in India, which can be seen to have increased in the recent years. The number of states with a prevalence of preterm birth 10% and over increased drastically from NFHS-4 to NFHS-5. Bigger states like Bihar and Rajasthan reporting a more than 15% prevalence of preterm births during NFHS-5 emerged as a cause for concern.

Table 1 presents the sample distribution of the study population. It also shows the prevalence of neonatal mortality and preterm birth by various background characteristics of the sampled children. The study included a total sample size of 164,825 total births, of which 19,887 (12.34%) were preterm births and 1.56% died within the first 28 days of life after birth. Of total sampled births, 46% of the births were female, one third of the births were of first order (33.4%) and 31% had birth interval of 24–48 months. Almost 24% of the birth were from caesarean section, 88% of mothers had received iron and folic acid tablets and 83% had at least two tetanus toxoid injections during their

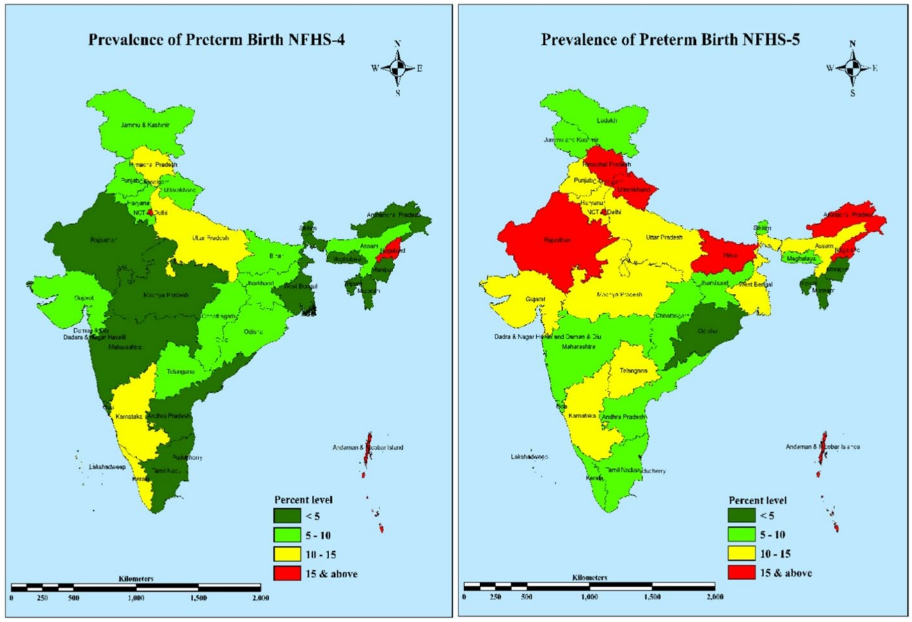

Fig. 5 Prevalence of preterm births among different states in India, NFHS-4 (2015–16) and NFHS-5 (2019–21), India

pregnancy. Around 73% of births occurred in rural areas and most of the mothers (69%) had received at least secondary level of education.

Notable, the neonatal mortality rate was higher among preterm births than non-preterm births (3.80% vs. 1.25%), male child (1.69% vs. 1.41%), births which occurred after onset of COVID-19 in country (3.11% vs. 1.45%) and with births interval < 24 months (1.98%). The prevalence of neonatal mortality was highest among short heighted mothers (height < 145 cm) and it decreased with increasing maternal height. The neonatal mortality prevalence was also higher when births occurred to uneducated women, lower wealth quintile, mothers > 35 years age at the time of delivery, mothers who smoked and belong to the central region of the country.

Further, among all neonatal mortalities, 12.34% of the births were preterm. The proportion of preterm birth was marginally higher among male children and those with a birth interval of less than 24 months. The prevalence of preterm births was lower when mother took IFA tablets and 2 or more TT injections during the pregnancy and has antenatal care visits. The percentage of preterm birth was higher at younger (< 19 years) and older maternal age (> 34 years) and among mothers with no formal education (13.5%). Although the prevalence did not vary much by wealth quintile of household, STs had the lowest prevalence of preterm births whereas Northern region had the highest prevalence of preterm births (17%).

Table 2 presents the results obtained from the discrete-time hazard model that has been adjusted for various socio-economic factors affecting neonatal mortality in India. An OR of 0.31 (log t) suggests that as time (t) increases, the likelihood of neonatal mortality decreases significantly. After controlling for other socioeconomic and program-level factors, the risk of neonatal mortality was significantly higher among preterm births (OR = 3.09, 2.77–3.45) compared to full-term births. The risk of neonatal mortality was 20% higher among male child (OR = 1.20, 1.08–1.33), 18% less for mother whose height is in the range of 145-149cm, 27% high for smokers (OR = 1.27, 1.04–1.56) and 31% high for caesarean births (OR = 1.31, 1.15–1.50) in comparison to those with female

Table 1 Sample distribution and prevalence of neonatal mortality and pre term births by socio-economic characteristics in India

Variable	Percent distribution		Neonatal mortality			Preterm birth		
	N	%	*N*	%	*p*-value	*N*	%	*p*-value
Neonatal death								
No	1,62,264	98.44		NA		782	29.93	< 0.01
Yes	2561	1.56				19,105	12.06	
Birth type								
Preterm birth	19,887	12.34	782	3.80	< 0.01		NA	
Full term birth	1,44,938	87.66	1,779	1.25				
Child sex								
Female	76,353	46.11	1,055	1.41	< 0.01	9069	12.20	< 0.05
Male	88,472	53.89	1,506	1.69		10,818	12.50	
Birth time								
Before Covid	1,52,410	93.11	2,191	1.45	< 0.01	18,408	12.40	> 0.10
Post-COVID-19 onset	12,415	6.89	370	3.11		1479	11.50	
Birth interval								
First Birth	55,003	33.82	880	1.59	< 0.01	6858	12.50	< 0.01
< 24 months	25,801	16.19	500	1.98		3323	13.20	
24–48 months	52,046	30.91	701	1.33		6101	12.20	
>48 months	31,975	19.08	480	1.54		3605	11.60	
Mother's height								
< 145 cm	18,621	11.75	425	2.22	< 0.01	2206	12.40	> 0.10
145–149 cm	42,025	25.53	722	1.69		5079	12.70	
150–154 cm	55,883	33.83	809	1.50		6729	12.30	
>=155 cm	48,296	28.90	605	1.26		5873	12.00	
IFA tablets during pregnancy								
No	20,960	12.24	425	2.11	< 0.01	2670	13.70	< 0.01
Yes	1,43,865	87.76	2,136	1.49		17,217	12.10	
No. of TT injections before birth								
No	10,020	5.24	219	2.50	< 0.01	1290	13.40	< 0.01
1	19,518	11.68	356	1.88		2510	12.60	
2 or More	1,35,287	83.08	1,986	1.46		16,087	12.20	
Antenatal care visits								
No ANC	10,731	6.15	275	2.77	< 0.01	1473	14.00	< 0.01
Any ANC	1,54,094	93.85	2,286	1.49		18,414	12.20	
Delivery by caesarean section								
No	1,29,915	76.24	2,064	1.64	< 0.05	15,697	12.50	> 0.10
Yes	34,910	23.76	497	1.33		4190	11.70	
Alcohol								
No	1,62,164	99.44	2,517	1.56	> 0.10	19,672	12.40	< 0.01
Yes	2,661	0.56	44	1.97		215	9.40	
Smoking								
No	1,54,440	96.74	2,375	1.54	< 0.05	19,026	12.40	< 0.01
Yes	10,385	3.26	186	2.30		861	11.00	
Mother's age at delivery								
< 19	14,689	9.95	248	1.80	< 0.01	1830	13.00	< 0.01
20–24	65,540	41.52	918	1.40		8113	12.60	
25–29	53,452	31.93	773	1.43		6323	11.90	
30–34	22,352	12.40	401	1.91		2604	12.00	
35+	8,792	4.20	221	2.66		1017	13.10	
Educational status								
No education	33,809	19.71	736	2.34	< 0.01	4184	13.50	< 0.01
Primary	20,306	11.80	400	1.95		2402	12.50	
Secondary	86,360	51.59	1,204	1.40		10,177	11.90	

Table 1 (continued)

Variable	Percent distribution		Neonatal mortality			Preterm birth		
	N	%	*N*	%	*p*-value	*N*	%	*p*-value
Higher	24,350	16.90	221	0.91		3124	12.30	
Wealth quintile								
Poorest	42,413	23.19	877	2.15	< 0.01	4746	12.40	< 0.01
Poorer	37,971	21.28	710	2.01		4574	12.80	
Middle	32,277	19.66	437	1.41		3886	11.80	
Richer	28,752	19.14	343	1.28		3605	12.20	
Richest	23,412	16.72	194	0.69		3076	12.40	
Caste								
SC	32,768	22.75	608	1.81	< 0.01	4208	12.40	< 0.01
ST	33,876	10.12	477	1.75		3446	10.20	
OBC	62,098	43.02	995	1.54		7578	12.60	
Others	36,083	24.12	481	1.31		4655	12.70	
Religion								
Hindu	1,20,957	79.70	1,996	1.58	< 0.01	14,929	12.30	< 0.01
Muslim	23,296	15.79	359	1.65		2786	12.90	
Others	20,572	4.51	206	1.00		2172	10.40	
Place of residence								
Urban	34,546	27.39	382	1.10	< 0.01	4232	11.60	> 0.10
Rural	1,30,279	72.61	2,179	1.74		15,655	12.60	
Region								
North	31,018	13.54	377	1.26	< 0.01	4875	16.90	< 0.01
Central	40,180	26.18	899	2.26		5268	14.00	
East	31,140	26.09	610	1.73		3423	12.30	
North-East	26,172	4.16	299	1.54		2598	10.60	
West	14,999	12.82	189	1.11		1406	9.00	
South	21,316	17.21	187	0.84		2317	9.30	

child, maternal height of <145 cm, non-smokers and normal delivery respectively. However, the risk of neonatal mortality was lower among longer birth intervals (> 48 months) as compared to first birth. Additionally, children born to mothers who had 2 or more TT injections during pregnancy (OR = 0.81, 0.66-0.98), and went for antenatal check-ups (OR = 0.66, 0.56–0.79) were significantly less likely to experience neonatal mortality as compared to children born to mothers who had less than 2 TT injection and made no antenatal care visit. A significant negative relationship was observed between neonatal mortality and increasing mother's height. Children born to mothers who had higher and above educational attainment (OR = 0.65, 0.52–0.82) were significantly less likely to experience neonatal mortality as compared to children born to uneducated mothers. The risk of neonatal mortality was significantly higher in central region (OR = 1.40, 1.19–1.65) and least in Southern region (OR = 0.72, 0.57–0.91) with reference to north region. The complimentary log-log model indicates that unobserved heterogeneity at the maternal level (frailty) is not statistically significant.

Population Attributable Risk (PAF) was calculated to estimate the possibility of reducing neonatal deaths among children as a proportion of total preterm births. The PAF is the ratio between preterm birth and non-preterm birth, meaning that it represents the fraction of the neonatal deaths that would remain if the babies born were non-preterm. We found that 19.4% (CI: 16.8% to 21.9%) of neonatal deaths and around 15% each of infant deaths (CI: 13.3% to 17.5%) and 14.8 % of under-five deaths (CI: 12.7% to 16.8%)

Table 2 Effect of socio-economic and demographic factors on neonatal mortality in india using discrete time hazard model, NFHS-5

Background variables	Odds ratio	Lower limit	Upper limit
Log t			
Time variable	0.31	0.30	0.33
Birth type			
Full term birth®			
Preterm birth	3.09	2.77	3.45
Child sex			
Female®			
Male	1.20	1.08	1.33
Birth time			
Before Covid®			
Post-COVID-19 onset	1.89	1.63	2.19
Birth interval			
First Birth®			
< 24 months	0.90	0.77	1.04
24–48 months	0.60	0.52	0.69
>48 months	0.65	0.55	0.77
Mother's height			
< 145 cm®			
145–149 cm	0.82	0.70	0.96
150–154 cm	0.72	0.62	0.85
>=155 cm	0.75	0.63	0.88
IFA tablets during pregnancy			
No®			
Yes	0.92	0.80	1.06
No. of TT injections before birth			
No®			
1	1.00	0.79	1.25
2 or More	0.81	0.66	0.98
Antenatal care visits			
No ANC®			
Any ANC	0.66	0.56	0.79
Delivery by caesarean section			
No®			
Yes	1.31	1.15	1.50
Alcohol			
No®			
Yes	1.15	0.77	1.71
Smoking			
No®			
Yes	1.27	1.04	1.56
Mother's age at delivery			
< 19®			
20–24	0.96	0.80	1.15
25–29	1.08	0.88	1.32
30–34	1.52	1.21	1.90
35+	1.91	1.47	2.49
Educational status			
No Education®			
Primary	1.09	0.93	1.28
Secondary	0.87	0.76	1.00
Higher	0.65	0.52	0.82
Wealth quintile			

Table 2 (continued)

Background variables	Odds ratio	Lower limit	Upper limit
Poorest®			
Poorer	1.05	0.91	1.20
Middle	0.84	0.71	0.99
Richer	0.71	0.59	0.87
Richest	0.61	0.48	0.79
Caste			
SC®			
ST	0.82	0.69	0.97
OBC	0.86	0.75	0.99
Others	0.83	0.70	0.98
Religion			
Hindu®			
Muslim	1.04	0.89	1.22
Others	0.64	0.51	0.81
Place of residence			
Urban®			
Rural	1.08	0.93	1.26
Region			
North®			
Central	1.40	1.19	1.65
East	1.23	1.03	1.47
North-East	0.85	0.68	1.07
West	1.09	0.87	1.37
South	0.72	0.57	0.91
Mother level Random effect	0.043 (Standard error = 0.2777)		

®Indicates the reference category

Table 3 Population attributable risk estimates for neonatal mortality, infant mortality and under-five mortality associated with preterm birth in India, NFHS-5

	PAF estimate	Minimum	Maximum
Under-five mortality	0.148	0.127	0.168
Infant mortality	0.154	0.133	0.175
Neonatal mortality	0.194	0.168	0.219

could be prevented if preterm birth was completely eliminated assuming all the socio-demographic characteristics remained the same (Table 3).

Table 4 shows the results obtained from logistics regression analysis. Preterm birth was the strongest predictor of neonatal mortality, with an adjusted odds ratio (AOR) of 3.24 (95% CI: 2.96–3.54). Female infants, children of second or third birth order, and those born to taller mothers (> 155 cm) had significantly lower odds of neonatal death. Antenatal care (ANC), especially four or more visits (AOR: 0.65), and receiving two or more TT injections during pregnancy also showed a protective effect. Private health facility births, older maternal age (30+), and residing in the Central or Eastern regions were associated with significantly higher odds of neonatal mortality.

4 Discussion

Achieving Sustainable Development Goals (SDG, target 3.2) to end preventable deaths of newborns and children under the age of five years would, to a large extent, depend on reducing preterm births as they are a major contributor to neonatal, infant, and

Table 4 Unadjusted and adjusted effect of preterm birth and various socio-economic factors on neonatal mortality in India, NFHS-5

Background characteristics	Labels	Neo-natal mortality	
		OR (95% CI)	**AOR (95% CI)**
Birth type	Full term ®		
	Preterm	3.25*** (2.99 3.54)	3.24***(2.96 3.54)
	Cons	0.01(0.01 0.01)	
Child sex	Male®		
	Female		0.81*** (0.75 0.88)
Birth order	1®		
	2–3		0.69***(0.63 0.77)
	4–5		0.85**(0.73 0.98)
	6+		1.12 (0.90 1.38)
Mother's height	< 145 cm®		
	145–149 cm		0.83***(0.73 0.94)
	150–154 cm		0.76***(0.67 0.86)
	> 155 cm		0.72***(0.63 0.82)
During pregnancy given iron syrup	No®		
	Yes		0.96 (0.85 1.08)
No. of TT injections before birth	No®		
	1		0.89 (0.74 1.07)
	2 or More		0.76***(0.65 0.88)
No. of antenatal care visits	None®		
	1–3		0.79***(0.68 0.92)
	4+		0.65***(0.56 0.75)
Delivery by caesarean section	No®		
	Yes		1.11* (0.99 1.25)
Place of delivery	Home®		
	Public health facility		0.87**(0.77 .99)
	Private health facility		1.24*** (1.07 1.45)
Mother's age at delivery	< 19®		
	20–24		0.93 (0.80 1.08)
	25–29		1.08 (0.92 1.27)
	30–34		1.28***(1.06 1.54)
	35+		1.56***(1.26 1.95)
Educational status	No education®		
	Primary		1.13* (0.99 1.28)
	Secondary		0.94 (0.84 1.06)
	Higher		0.65***(0.54 0.78)
Wealth quintile	Poorest®		
	Poorer		1.06 (0.95 1.18)
	Middle		0.85 (0.75 0.97)
	Richer		0.76*** (0.65 .89)
	Richest		0.53***(0.43 0.66)
Caste	SC®		
	ST		0.87** (0.76 0.99)
	OBC		0.89** (0.80 0.99)
	Others		0.89(0.78 1.02)
Religion	Hindu®		
	Muslim		0.97 (0.86 1.1)
	Others		0.72***(0.60 0.87)
Place of residence	Urban®		
	Rural		1.06 (0.94 1.2)

Table 4 (continued)

Background characteristics	Labels	Neo-natal mortality	
		OR (95% CI)	**AOR (95% CI)**
Region	North®		
	Central		1.54***(1.35 1.77)
	East		1.25*** (1.08 1.45)
	North-East		0.84* (0.70 1.01)
	West		1.03 (0.85 1.24)
	South		0.79***(0.66 0.96)

under-five mortality. Our findings indicate that India witnesses around 12.34% preterm births and the prevalence of preterm births has dramatically increased over the years. A thorough literature review indicate that observed preterm birth rate in India is higher than the global estimate of 10.6%, and that of most countries in the world, including Pakistan (8.4%), Indonesia (10.4%), China (6.9%), Nigeria (11.4%), Ethiopia (12.0%), US (9.6%), and Brazil (11.2%) [1]. In parallel, our findings also show that the contribution of neonatal deaths to infant mortality (70%) and under-five mortality (60%) has been increasing in India. This study found huge disparities in preterm birth rates at the sub-national level, ranging from less than 5% in Lakshadweep and Manipur to over 25% in Uttarakhand and Himachal Pradesh.

Understanding factors contributing to preterm births would benefit policy makers to target appropriate interventions to reduce preterm birth and its associated complications. Literature suggests that the causes of preterm birth are multi-factorial, including clinical, biological, behavioural, and socioeconomic [17–19]. Studies suggest that maternal age, maternal anaemia, history of smoking, previous preterm birth, interpregnancy interval of less than six months, multigravida, and alcohol consumption are risk factors for preterm birth [20–22]. Other studies have found that women from rural areas and those belonging to the lowest quintile of deprivation are at a higher risk of preterm births [23, 24]. Consistent with the literature [24–28] our study found that women over the age of 35 years, those belonging to the lower wealth quintile, those with higher birth order, those who had a C-section were more likely to experience preterm birth. Similar to other studies [29, 30] we also found that ANC visits were associated with a reduction in preterm birth as effective ANC programs provide an opportunity to intervene early to prevent preterm births [31]. Our study found that women with no formal education experienced the most preterm births. A meta-analysis across 12 European countries suggested that lower maternal education was associated with an appreciable risk of preterm birth [32]. Likewise, two studies from Bangladesh concluded that preterm rates decrease with an increase in women's educational levels [33, 34]. This underscores the importance of awareness and educational programs aimed at mothers to reduce the number of preterm births.

Preterm births are a leading cause of early neonatal deaths and account for 35–46% of all neonatal deaths [6, 23, 35]. In addition, there are short- and long-term sequelae among preterm babies who survive. Babies that survive preterm birth suffer lifelong morbidities and face increased risks of neuro-developmental impairment, hypertension, chronic lung disease, glucose intolerance, and stunted growth [36–39]. Globally, 144 million under-five children had stunted growth in 2020 [40]. Moreover, preterm birth has been found to be associated with twice higher risk of being stunted [41, 42]. India has the highest number of stunted children (46.6 million) in the world and accounts for one-third of the global share [43].

An observed rise in preterm births over time may partly reflect improved survival due to greater availability of fertility treatments, antenatal corticosteroids, and neonatal care. Studies have shown that access to assisted reproductive technologies has been associated with a higher likelihood of preterm deliveries, as these often involve multiple gestations or induced early labor [1]. Additionally, improved awareness among pregnant women regarding signs of preterm labor and more timely care-seeking behavior may reduce the likelihood of stillbirths or late spontaneous abortions, instead resulting in live preterm births [44]. These shifts highlight the importance of interpreting preterm birth trends in the context of evolving health system capacities and maternal care-seeking practices. It is important to interpret the observed increase in preterm birth prevalence with caution, as gestational age was recorded in completed months, not weeks, across all NFHS rounds. This may lead to an overestimation of preterm births compared to clinical definitions (< 37 weeks). While our definition (< 9 months) is consistent across all waves, it does not capture precise gestational age, and differences in respondent recall or interpretation may also contribute to the observed trend.

India launched the New-born Action Plan in 2014 and has implemented a number of interventions targeting mothers and new-borns during the antenatal, natal, and postnatal periods. However, a number of concerns still need addressing. For example, a report by MOH observed that about 50% of districts under the programme did not have a neonatal intensive care unit and that only about 50% of such units had adequate doctors and nurses [45]. There is evidence to suggest that antenatal steroids are effective in reducing neonatal mortality in India by reducing the risk of respiratory distress syndrome [46]. A facility based survey in India have reported that most of the facilities in India are not equipped for providing quality care for threatened preterm birth and lacked competent workforce, physical resources and failed to fulfil preconditions outlined by WHO [47]. A recent UNICEF report showed that the use of antibiotics for premature rupture of membrane and the use of magnesium sulphate in the management of eclampsia was just 11% in India [48]. Similarly, a recent study mapping Neonatal Mortality Rate at the subnational level estimated that 430 (59%) districts would need significant improvement to reach the SDG 2030 NMR target from its current rates [49]. India needs to further strengthen its maternal and child health services and scale up its efforts to reduce preterm birth and its associated complications. The good news is that three of every four premature infants can be saved with the existing low-cost interventions provided during the antenatal, natal, and postnatal periods [15]. Such interventions include screening antenatal women at risk of preterm deliveries, administering antenatal steroid injections, providing iron and micronutrient supplementation, treating infections with antibiotics, and offering safe kangaroo mother care [50, 51].

A recent study estimated that using Chlorhexidine and antibiotics can respectively save 122,525 and 43,926 neonatal lives over 10 years in India [48]. Accelerating the implementation of and scaling up of such low-cost interventions will significantly reduce the risk of preterm births in India. In addition, further efforts to encourage institutional delivery are needed since inter-partum measures like delayed cord clamping and maintaining body temperature are more feasible in an institutional setting. Furthermore, improving the understanding of the causes of preterm birth and increasing the availability of more robust data at the local level would enable effective strategies to be appropriately targeted to reduce the burden of preterm births.

4.1 Strengths and limitations

The strength of our study lies in its use of a large-scale nationally-representative sample to study the trend of preterm birth, identify contributing factors associated with it, and analyse its association with neonatal mortality in India. There are, nevertheless, a few limitations of our study. Given that the NFHS collects gestational data in months rather than weeks, this study was not able to use the precise WHO definition of 37 weeks of gestation to define preterm births nor to classify them into preterm births. This limitation could result in overestimation or underestimation of true preterm birth rates. Such misclassification may attenuate the strength of observed associations or obscure differences in neonatal outcomes. Caution is also advised when interpreting the trend of preterm birth over time as this may exaggerate the prevalence of preterm births due to issues around awareness, reporting and quality of data during the NFHS-3, and increase in institutional deliveries over time. Second, the use of self-reported reproductive calendar data introduces the risk of recall bias, especially when respondents are asked to recall events from up to five years prior. Such inaccuracies may impact the timing and classification of births. Third, changes in health service utilization, particularly increased institutional deliveries over successive NFHS rounds, may have influenced reporting quality and completeness. We did not conduct interaction analyses, which may limit the understanding of how certain variables jointly influence the outcomes. However, our estimation of PAFs provides complementary insights into the relative public health impact of different risk factors.

In conclusion, with the high burden of preterm births, India urgently needs to accelerate investment in primary interventions offered to women during pregnancy to prevent preterm births and scale such interventions up. Given that India is the single largest contributor to babies born preterm globally, the achievement of SDG-3 and of specific neonatal and child mortality targets may, to a large extent, depend on India's progress in preventing preterm births.

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Author contributions
PD and MB, conceptualised the study and PB, MB, CB were responsible for writing the original draft. PD, SS and LKD were involved with formal analysis of the data. All the authors contributed to the editing, verification and the final manuscript.

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Data availability
Availability of Data and Materials:This study uses secondary data which is available on request through DHS website https://dhsprogram.com/data/dataset/India_Standard-DHS_2020.cfm? flag=1.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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