BMC Pregnancy and Childbirth

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Unraveling the complexity of selected adverse neonatal outcomes in India: a multilevel analysis using data from a nationally representative sample survey

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Abstract

Introduction The burden of adverse neonatal outcomes (ANOs), encompassing preterm birth(PTB), low birth weight(LBW), and early neonatal deaths, remain significant public health challenge globally, particularly in developing countries. The study aims to provide estimates of adverse birth outcomes and examine their correlates by using a multi-level model analysis at individual/household/community level.

Methodology The study has chosen three ANOs such as preterm birth(PTB), low birth weight(LBW), and early neonatal deaths (based on available data) for constructing a combined indicator which is calculated by the presence of any one of these variables. We used National-Family-Health-Survey India data(2019–21). Multilevel(three-level) logistic regression model was used to find the probability of binary adverse neonatal outcomes with the effects of individual/household/community level variables among the recently delivered women.

Result Between 2019–21, a total of 26.5% ANOs were reported from 1.7 million pregnant women surveyed, a rate that has increased since 2005–06 (20%). Final multilevel model asserts that women having higher education [OR 0.92, 95%CI 0.88, 0.96), and those registered for antenatal checkups (OR 0.95, 95%CI OR 0.9, 0.99) and know all components of birth-preparedness-and-complication-readiness (OR 0.88, 95%CI 0.84, 0.92) have a higher protective odd of having adverse outcomes. Difficulty in seeking medical help (OR 1.2, 95%CI 1.15, 1.25) and belonging to poor wealth status and no intention to become pregnant (OR 1.11 95% CI 1.05, 1.18) acts as a risk factor. Multilevel model with household, community and district level variables added to the null model showed a decline in the ICC values to 4.7%, 18.8% and 30.9% respectively across district, community, and household levels.

Conclusion The study underscores that specific ANOs in India has shown an increase, prompting significant concern. There is need to institute a mechanism for generating knowledge amongst women to protect them from unwanted pregnancies and later adverse outcomes.

Keywords Adverse neonatal outcome, ANOs, LBW, Preterm birth, Early neonatal death, SDG

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Background

The burden of adverse neonatal outcomes [1–4] (ANOs), encompassing preterm birth, low birth weight, and early neonatal deaths, remain significant public health challenge globally, particularly in developing countries. These outcomes not only affect the immediate health of newborns but also have long-term implications on their development and well-being [5]. The global estimates of preterm birth is 10.6%, accounting for approximately 15 million each year [6] and about one in every seven newborn is born with low-birth weight (LBW) [7], which is over 20 million [8] each year. Preterm birth and LBW are significant contributors to neonatal mortality [9, 10] and strongly indicate potential growth issues and nutritional deficiencies in children, affecting their physical and cognitive development in later stages of life [11, 12]. In 2019, about half of all under-5 deaths occurred globally in the first 28 days of life, of which three-fourth died in the first week [13]. South Asia, being significantly affected accounts for more than one-third of the burden of preterm birth [14], and nearly half of the burden of LBW [15].

India continues to grapple with a high burden of ANOs despite of making progress in various health indicators. Approximately 12% of children were born preterm, and 18% had low birth weight in India during 2019–21 [16], which is higher than its neighboring countries such as Sri Lanka, Nepal, Myanmar, and China [17]. Preterm birth and LBW are responsible for approximately 28% [18] and 60% [19] of neonatal deaths respectively in India.

These adverse neonatal outcomes are affected by a variety of determinants. Previous studies have shown that *maternal individual factors*, such as maternal age, height, weight, any chronic health conditions, particularly hypertensive disorders and diabetes [9, 16, 20–24]; *lifestyle factors*, such as smoking, tobacco intake, alcohol, and drug use during pregnancy [20, 21]; and *socio-demographic factors*, such as wealth status, education level, residence, and environmental factors [16, 22, 23, 25, 26] contribute significantly to the increased risk of ANOs. Additionally, obstetric factors such as previous history of adverse birth outcome, any pregnancy complication, birth order, and potential risk factors during pregnancy were highly associated with adverse neonatal outcomes [16, 24, 27, 28]. Other factors such as inadequate antenatal care [24, 26, 27, 29, 30], inadequate intake of Iron Folic Acid (IFA) supplements during pregnancy [8, 31], sanitation practices by mothers [32], environmental pollution [33–35], and violence [36] were considered as risk factors for preterm birth and LBW.

In order to prevent these ANOs, a number of programmatic initiatives and policies have been dedicated in recent years by Government of India and different state government. These include promoting early registration of pregnancy, improving the quality antenatal checkups, promoting institutional deliveries by reducing out of pocket expenses through different schemes like Janani Shishu Suraksha Karyakram (JSSK) and Janani Suraksha Yojana (JSY) program, skilled birth attendants, kangaroo mother care, postnatal check-ups for both the mother and the newborn, early initiation of breastfeeding, exclusive breastfeeding, age-appropriate supplementary feeding, immunization, and home-based newborn and young child care [13, 18, 37, 38]. Implementation of these programs contributes to significant progress in reducing neonatal mortality rate (NMR) over the last decade from 31 per 1000 livebirths in 2011 [39] to 20 per 1000 livebirths in 2020 [40]. However, it is still irreconcilably high for a country that aspires to achieve Sustainable Development Goal target 3.2 (SDGs) related to child survival.

Despite decades of research investigating risk factors for adverse neonatal outcomes, most of the studies [16, 23, 26, 32] have assessed only household and individual factors. Gaps remain in understanding how community and health seeking factors might contribute to the neonatal outcomes. In the global context, studies have demonstrated that, community-level factors have also an impact on individual level health outcomes [41–43] particularly in developing countries. *These factors may be potentially important for understanding population-based shifts in distribution of risk factors associated with the outcomes. Therefore, along with individual and household level factors, community-based determinants are crucial for more comprehensive understanding of the risk factors.*

Thus, given the background, the purpose of this paper is to *provide estimates and trends of selected adverse neonatal outcomes and examine their correlates by using a multi-level model analysis at individual, household, and community level*. This study uses the latest nationally representative data from National Family Health Survey (NFHS)−5 of India 2019–2021. This study offers a comprehensive analysis of factors influencing adverse neonatal outcomes, furnishing vital insights for crafting policy decisions and intervention strategies to enhance newborn health.

Methods

Data and samples

The analysis is based on data gathered from India's National Family Health Survey (NFHS) of its fifth round. The NFHS is one of large-scale, multi-round survey conducted in representative samples throughout all the states and union territories of India. It compiles information about fertility and mortality, reproductive, maternal, child and adolescent health status, healthcare utilization, high risk behaviors, domestic violence, etc. The data used

for this study has been downloaded from DHS data program portal after the prior registration and permission. There are no identifiers in the data which is available in the public domain thus has no ethical implication. [44]

Although literature suggests range of ANOs [1–4] but based on available data in NFHS, the study has chosen *three adverse neonatal outcomes* from individual data set such as Low Birth Weight (birth weight ≤ 2500 gm), Pre-term birth (Birth ≤ 37 Weeks of pregnancy period) and Early Neonatal death (death happened between 7 or below days) for constructing a combined indicator for adverse outcomes. An adverse neonatal outcome is calculated by the presence of any one of the following three variables. Out of 724,115 participants' information for the last five years survey period which is available in this data set, the study chose latest pregnancy (this analysis considered only the most recent pregnancy information) outcomes of 174,947 mothers for the analysis. *This selection was done to explore medical level variables which are available for the latest pregnancy only.*

Conceptual framework

An intricate web of maternal determinants spanning individual, household, and community levels, as well as factors within the healthcare system can contribute to the occurrence of adverse neonatal outcomes. Through an extensive review of literature, a comprehensive range of variables [5, 45–61] was identified and later included in the framework for further analysis (Fig. 1).

For comprehensive analysis, we have categorized the variables into *individual factors*, which encompass obstetric-related factors, maternal individual factors, and factors related to health service utilization. Additionally, *household-level* and *community-level factors* were also included in the analysis. These existing variables not only provided critical insights into socio-demographic and economic characteristics but also into health service utilization and associated factors (Fig. 1).

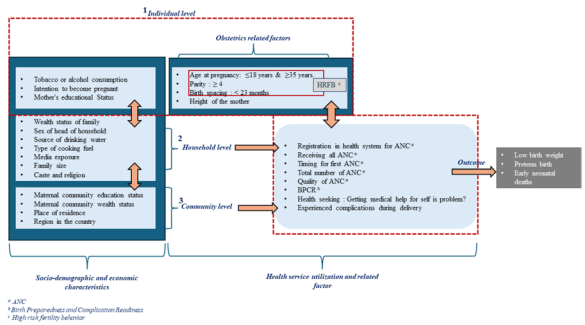

Fig. 1 Conceptual framework depicting association of individual, household, and community level factors with adverse neonatal outcomes

Outcome of interest and list of variables

The ANOs among the latest births consists of pre-term births, LBW and Early Neonatal deaths, compositely labelled as the outcome indicator. To understand the association between ANO and background characteristics of mothers, the study considered twenty-two explanatory variables for the analysis. These variables comprise of *Individual level* factors such as High-risk fertility behavior, Mother's educational Status, Height of the mother, Tobacco or alcohol consumption by mother, Intention to become pregnant, received antenatal care (ANC), ANC registration status, Timing of first ANC checkup, Number of ANC checkups, Perceived Birth Preparedness and Complication Readiness (BPCR), Getting medical help for self is problem, Perceived quality of antenatal checkups, Experienced complications; *Household level factors* that includes Wealth index, Sex of the household head, Source of drinking water, Type of cooking fuel, Media Exposure, Family size, Caste, and Religion; *Community level factors* such as Residential Status, Women community education status, women community economic status, Region (S1 Appendix).

For further analysis we have formed various composite indexes using various dichotomous/ nominal/ ordinal variables.

- '*High Risk Fertility Behavior*' which is defined as exposure of women to any of the following three demographic risks at their last childbirth: maternal age ≤ 18 years or ≥ 35 years, birth order ≤ 4, and birth interval < 24 months.
- '*Birth Preparedness and Complication readiness*' (BPCR, *Cronbach* $\alpha = 0.90$) BPCR was computed by summing up the scores from eleven variables like if women were told about complications due to: vaginal bleeding, convulsions, prolonged labor, severe abdominal pain, high blood pressure; Importance of: institutional delivery, cord care, breast feeding, keeping baby warm, family planning and where to go for pregnancy complications/delivery. This composite score ranges between '0' and '11', further categorized as 'No BPCR', '1–10 BPCR' and 'All BPCR'.
- '*Getting medical help for self is problem*' (*Cronbach* $\alpha = 0.88$): DHS collects information on women facing any difficulty in seeking medical help. This information ranged from problems concerning permission to go, getting money needed for treatment, distance to health facility, having to take transport, not wanting to go alone, concern no female health worker, concern no provider, concern no drugs available. A score was generated using these variables named. The score ranges between '0' and '16' which was further

categorized as '0-No', '1–5 – Low', '6–10 – Moderate' and'11–16 – High'.

- '*Perceived quality of antenatal checkups*' (*Cronbach α = 0.75)*: The score for perceived quality from five ANC has been calculated by aggregating each service score. These ANC services during pregnancy are weight measurement done regularly, blood pressure taken, urine sample taken, blood sample taken as well as given/taken iron tablet/syrup. The total score ranges between '0' and '5' and further categorized as '0–4 – None/Some' and '5- All'.
- 'Experienced complication' (*Cronbach α = 0.62*): This was estimated from five types of complications experienced by mothers during the pregnancy such as convulsions not from fever, swelling of the legs, body or face, breech presentation, prolonged labor, and excessive bleeding. The total score ranges between '0' and '5' and categorized as; '0 – No', '1- Anyone', '2 – Any two' and '3–5 – Three & Above'.
- The study also constructed community level variables such as *Maternal community Education status* and *Maternal community Economic status* by aggregating household characteristics for the respondents to the community level (Primary Sample Units-PSUs). DHS provides household Wealth Index (WI) based on information collected on household amenities and assets. Based on state level household wealth index score, the community level economic status was categorized as 'high' and 'low' where the 'high' indicates those PSUs that are higher in terms of WI than that of state average and 'low' for the remaining. Similarly, community women educational index is created based the average years of schooling of women at the PSU level. Remarkably, this index is based only on the information of women aged 15–49 years since others were not part of survey.

Statistical analysis

The study employed both descriptive and inferential statistics for the analysis. First, percentage prevalence of adverse neonatal outcomes from NFHS-3, NFHS-4 and NFHS-5 rounds of survey were estimated. For detailed analysis i.e., bivariate and multilevel analysis we have only considered NFHS-5 data. Bivariate analysis was performed to examine the adverse neonatal outcomes with various individual, household as well as community level factors as explained in the conceptual framework. The initial bivariate analysis was conducted with $\chi 2$ test for ordered categorical variables. The study also employed Un-adjusted logistic regression (Odds Ratio) to check the statistical validity of such relationship. Later those with a significant difference ($P < 0.05$) and those biologically plausible were selected for the adjusted analysis.

Subsequently, multilevel (three level) logistic regression model was used to find the probability of binary adverse neonatal outcomes (No = 0, Yes = 1) with the effects of individual, household, and community variables among the recently delivered women. We have used random effect model of multiple logistic regression for the same. Within the multilevel analysis, we used the Intraclass Correlation Coefficient (ICC) to assess the proportion of total variance in adverse neonatal outcomes attributed to the differences at the individual, household, and community level variables. ICC helps determine whether multilevel modeling is appropriate by quantifying the degree of similarity in outcomes within clusters where a higher ICC implies significant portion of the variance due to clustering effects rather than individual-level factors. All statistical analysis was conducted through the statistical software STATA-Version 17.

Result

Sample characteristics

From a sample of 724,115 women delivered in past five years preceding the survey, we have included information from recently delivered women having 174,947 live births to capture variables stated in the framework (Fig. 1). The information is from nationally representative sample survey, including 707 districts and 36 states/union territories of India. Between 2019–21, a total of 26.5% (46,342 out of 174,947) adverse outcomes were reported, a rate that has increased since 2005–06, when 20% (8315 out of 19,764) adverse outcomes were documented (Fig. 2).

The prevalence of ANO was higher amongst women having high risk fertility behavior (27.7%), having height less than or equal to 150 cm (29%), and those who consume tobacco or alcohol (27.2%). It is imperative to note that those women who did not receive any antenatal checkups (28.2%), or even registered for ANC (28.9), had no knowledge about the birth preparedness and complication readiness components (28.4%), who felt that healthcare seeking was a problem due to family reasons (28.8%), perceived quality of ANCs as poor and had experienced any complication during pregnancy(80.3%) had higher ANOs (Table 1).

At household level women belonging to poor wealth status (28.3%), using unclean fuel (27.6%), no media exposure (28.7%), family size more than 6 (27.0%), belonging to OBC caste (27.6%), and belonging to Hindu religion (26.8%) had higher adverse outcomes. At the community level, women residing in the rural areas (27.1%), having poor maternal community education (28.4%) and economic status (27.5%) and residing in the central region (29.7%) had higher ANOs (Table 1).

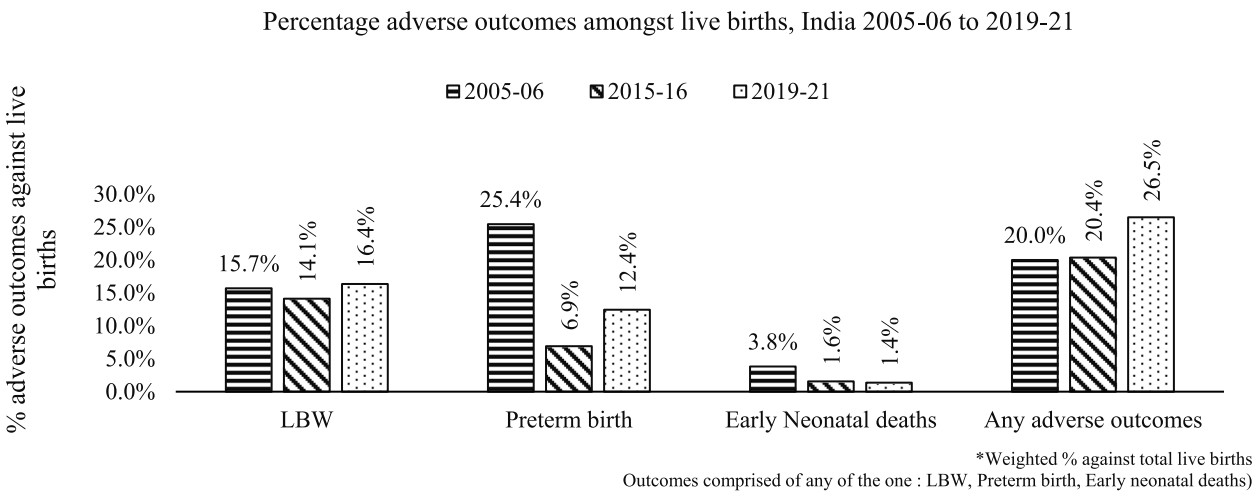

Fig. 2 Percentage adverse outcomes amongst live births, India 2005–06 to 2019–21

Results of bivariate and regression analysis

The results from bivariate analysis elucidate that odds of having adverse outcomes are marginally more amongst women having HRFB and having no intention for current pregnancy. A disaggregated analysis by maternal age noted no significant difference of ANOs between different age groups. Protective factors include good maternal height (OR 0.78; 95% CI 0.76, 0.80), higher education (OR 0.76; 95% CI 0.73, 0.78), ANC registration (OR 0.88; 95% CI 0.84, 0.92), ANC checkups (OR 0.91; 95% CI 0.87, 0.95), More than 4 ANC checkups (OR 0.82, 95% CI 0.78, 0.85), having knowledge about BPCR (OR 0.86; 95% CI 0.82, 0.89), women perceiving better quality of ANC (OR 0.89; 95% CI 0.86, 0.91) and having no complication during delivery also showed a protective odds of having adverse outcomes. Difficulty in seeking healthcare was also a risk factor.

Higher the wealth status (OR 0.78; 95% CI 0.76, 0.81), using clean fuel for cooking (OR 0.89; 95% CI 0.87, 0.91), having media exposure (OR 0.86; 95% CI 0.84, 0.88) and belonging to Muslim and other religion showed a protective odd of having ANOs. Within the community level variables belonging to rural areas (OR 1.12, 95% CI 1.09, 1.15), having poor maternal community education (OR 1.12, 95% CI 1.09, 1.16) and economic status (OR 1.07, 95% CI 1.04, 1.09) presented as risk factors.

Multilevel logistic regression analysis incorporated variables identified as significant in the bivariate analysis or are biologically plausible. Our analysis was conducted across three distinct models: *Model I* included explanatory variables at the individual level, *Model II* integrated variables from both individual and household levels, while the final model i.e., *Model III* encompassed all significant variables from the bivariate analysis or deemed biologically plausible from individual, household, or community levels (Table 2). Result from the *model III* asserts that women having higher education [OR 0.92, 95% CI 0.88, 0.96), with good height (OR 0.8, 95% CI 0.77, 0.82) and those who have registered for antenatal care checkups (OR 0.95, OR 0.9, 0.99) and know all the components of birth preparedness and complication readiness (OR 0.88, 95% CI 0.84, 0.92) have a higher protective odds of having adverse outcomes. It is imperative to note that difficulty in seeking medical help (OR 1.2, 95% CI 1.15, 1.25) and no intention to become pregnant (OR 1.11*** 95% CI 1.05, 1.18) is a risk factor for having adverse neonatal outcome(Table 2).

Further individual and community level variables assessment explains that in comparison to women belonging to poor wealth status those belonging to higher wealth status showed a higher protective odd of adverse outcomes. Women from Schedule tribe (OR 0.91, 95% CI 0.87, 0.95), belonging to Muslim (OR 0.95, 95% CI 0.92, 0.99) and other religion (0.92, 95% CI 0.87, 0.98) have also shower a lower risk of having adverse outcomes(Table 2).

Null model, a model without covariates analyzed using multilevel modeling of adverse neonatal outcomes (Table 3) presented a significant amount of variation across families, communities, and districts. The null model, which doesn't include any covariates, indicates significant variation in adverse neonatal outcomes across different levels: 6.2% of the variation is explained by district-level differences, 19.7% by community-level, and 31.3% by household-level differences. This suggests that these factors play a substantial role in influencing adverse neonatal outcomes (Table 3).

Result from the model III that is the model with household, community and district level variables added to

Table 1 Socioeconomic, demographic, and healthcare level factors associated with adverse outcomes amongst recently delivered women having live birth in India (2019–21) ($n = 174,947$)

Variables	ANO [weighted sample- ($n = 46,342$)]	Total births [weighted sample- ($N = 174,947$)]	%	Unadjusted OR
Individual level				
Age of women (5-year age group yrs.)				
15–19	1484	3397	30.4%	Ref
20–24	13,345	35,409	27.4%	0.84*** [0.79; 0.89]
25–29	17,119	50,577	25.3%	0.75*** [0.71; 0.80]
30–34	8616	27,720	23.7%	0.71*** [0.66; 0.75]
35–39	3447	11,142	23.6%	0.72*** [0.67; 0.77]
40–44	846	2759	23.5%	0.75*** [0.68; 0.83]
45–49	252	730	25.7%	0.85 [0.71; 1.02]
High risk fertility behavior				
No	30,013	115,895	25.9%	Ref
Yes	16,329	59,052	27.7%	1.09*** [1.07; 1.12]
Mother's educational Status				
Illiterate	9739	34,144	28.5%	Ref
Primary	5877	20,526	28.6%	1.01 [0.97, 1.04]
Secondary	23,731	90,071	26.3%	0.90*** [0.87, 0.92]
Higher	6996	30,206	23.2%	0.76*** [0.73, 0.78]
Height of the mother (in cm.) (Refusal = 5915)				
< = 150	18,562	64,057	29.0%	Ref
150–155	14,602	56,864	25.7%	0.85*** [0.83, 0.87]
> 155	11,589	48,111	24.1%	0.78*** [0.76, 0.80]
Tobacco or alcohol consumption (any mode)				
Yes	1,546	5,678	27.2%	Ref
No	44,796	169,268	26.5%	1.03 [0.98, 1.11]
Intention to become pregnant				
Then	42,288	160,964	26.3%	Ref
Later	2,084	7,078	29.4%	1.17*** [1.11, 1.23]
No more	1,971	6,905	28.5%	1.12*** [1.06, 1.18]
Received ante-natal care				
No	3,025	10,712	28.2%	Ref
Yes	43,318	164,235	26.4%	0.91*** [0.87, 0.95]
ANC registration status				
No	3,105	10,742	28.9%	Ref
Yes	43,237	164,205	26.3%	0.88*** [0.84, 0.92]
Timing of first ANC checkup of ANC visits				
First Trimester	31,941	122,534	26.1%	Ref
Second Trimester	9,092	32,852	27.7%	1.09*** [1.06, 1.12]
Third Trimester	2,198	8,509	25.8%	0.99 [0.94, 1.04]
Number of ANC checkups				
No ANC	3,025	10,712	28.2%	Ref
1- 4 visits	24,175	85,986	28.1%	0.99 [0.95, 1.04]
More than 4 visits	18,466	76,005	24.3%	0.82*** [0.78, 0.85]
Perceived Birth Preparedness and Complication Readiness (BPCR)				
None	5,140	18,105	28.4%	Ref
At least one	26,401	98,391	26.8%	0.93*** [0.89, 0.96]
All	14,801	58,451	25.3%	0.86*** [0.82, 0.89]
Getting medical help for self is problem?				
No	6,428	26,820	24.0%	Ref

Table 1 (continued)

Variables	ANO [weighted sample- (*n* = 46,342)]	Total births [weighted sample- (*N* = 174,947)]	%	Unadjusted OR
Low	11,522	46,343	24.9%	1.05*** [1.01, 1.09]
Moderate	16,361	59,950	27.3%	1.19*** [1.15, 1.23]
High	12,031	41,834	28.8%	1.28*** [1.24, 1.33]
Perceived quality of antenatal checkups				
None/Some	11,486.28	40,532.41	28.3%	Ref
All	34,856.04	134,414.50	25.9%	0.89*** [0.86, 0.91]
Experience of complications				
No	15,216	58,396	26.1%	Ref
Any one	11,330	43,450	26.1%	1.00 [0.97, 1.03]
Any two	10,698	39,957	26.8%	1.04*** [1.01, 1.07]
Three & more	9,098	33,145	27.4%	1.07*** [1.04, 1.11]
Household level				
Wealth index				
Poorest	11,269	39,839	28.3%	Ref
Poorer	10,463	36,811	28.4%	1.01 [0.98, 1.04]
Middle	8,799	34,249	25.7%	0.88*** [0.85,0.91]
Richer	8,630	33,650	25.6%	0.87*** [0.85, 0.90]
Richest	7,182	30,398	23.6%	0.78*** [0.76, 0.81]
Sex of the household head				
Male	39,292	148,557	26.4%	Ref
Female	7,050	26,389	26.7%	1.01 [0.98, 1.04]
Source of drinking water				
Unclean	1,628	6,337	25.7%	Ref
Clean	41,836	158,247	26.4%	1.04 [0.98, 1.10]
Type of cooking fuel				
Unclean fuel	21,731	78,807	27.6%	Ref
Clean fuel	21,845	86,270	25.3%	0.89*** [0.87, 0.91]
Media Exposure				
Not at all	13,454	46,814	28.7%	Ref
Less than/at least once	32,888	128,133	25.7%	0.86*** [0.84, 0.88]
Family size				
1 to 4	12,950	48,571	26.7%	Ref
5 to 6	17,066	65,853	25.9%	0.96** [0.94, 0.99]
> = 7	16,326	60,523	27.0%	1.02 [0.99, 1.04]
Caste				
General	8,475	32,694	25.9%	Ref
SC	10,953	39,627	27.6%	1.09*** [1.06, 1.13]
ST	4,418	17,291	25.6%	0.98 [0.94, 1.02]
OBC	19,800	75,232	26.3%	1.02 [0.99, 1.05]
Religion				
Hindu	37,263	139,207	26.8%	Ref
Muslim	7,224	27,843	25.9%	0.96*** [0.93, 0.99]
Other	1,856	7,897	23.5%	0.84*** [0.80, 0.89]
Community level				
Residential Status				
Urban	12,307	49,341	24.9%	Ref
Rural	34,035	125,606	27.1%	1.12*** [1.09, 1.15]
Maternal community education status				
High	39,341	150,337	26.2%	Ref

Table 1 (continued)

Variables	ANO [weighted sample- (*n* = 46,342)]	Total births [weighted sample- (*N* = 174,947)]	%	Unadjusted OR
Low	7,001	24,610	28.4%	1.12*** [1.09, 1.16]
Maternal community economic status				
High	35,878	136,882	26.2%	Ref
Low	10,465	38,065	27.5%	1.07*** [1.04, 1.09]
Region				
Southern	6,501	29,723	21.9%	Ref
Central	14,290	48,055	29.7%	1.51*** [1.46, 1.56]
North	3,315	11,276	29.4%	1.49*** [1.42, 1.56]
Eastern	11,662	45,129	25.8%	1.24*** [1.20, 1.29]
Northeastern	1,548	7,091	21.8%	1.00 [0.94, 1.06]
Western	9,027	33,673	26.8%	1.31*** [1.26, 1.36]

Authors calculation

$p < 0.05$**; $p < 0.001$***; not significant—no star sign [*p* value based on logistic regression results]

the null model showed a decline in the ICC values to 4.7%, 18.8% and 30.9% respectively across district, community, and household levels indicating that these variables account for some of the variation observed in the null model. This reduction in ICC values signifies that the included covariates help explain the variation in adverse neonatal outcomes across different levels, providing insights into how these factors contribute to the observed outcomes (Table 3).

Discussion

Our analysis on repeated large scale nationally representative data indicated that a total of 26% ANOs were reported from 1.7 million pregnant women surveyed, that has increased from 2005–06 to 2019–21. Preterm births have declined from 25.4% to 12.4%, early neonatal mortality has reduced from 3.8% to 1.4% while LBW has increased from 15.7% to 16.4%. Higher education, good knowledge about birth preparedness and complication readiness are protective against ANOs while difficulty in seeking medical help is a risk factor. The individual, household and district level factors explain 30% of the variation in ANO.

In line with other published literature, our descriptive analysis found that the prevalence of ANO was higher amongst women having high risk fertility behavior [59, 60] and those who consume tobacco or alcohol [50]. Literatures have emphasized the importance of antenatal checkups [54] and knowledge about birth preparedness and complication readiness components [53]. Various socioeconomic variables were also found to increase risk of having adverse outcomes like using unclean fuel [47, 48] and drinking water, having no media exposure, residing in rural area, and having low maternal community and economic status.

Scholarly literature indicates that among other social factors pertaining to mothers, education has been identified as the most influential determinant of health outcomes along with the wealth status [52]. In line with this finding and other literatures [56, 57, 62], our study also noted that women having higher education have less odds of having adverse outcomes. This could be due to various factors including better access to healthcare services, improved health literacy, enhanced decision-making skills regarding their own health and that of their children, greater economic resources, and increased social support networks. Additionally, higher education or better wealth status often correlate with healthier lifestyle choices and behaviors, contributing to better overall health outcomes for women and their offspring.

Another key finding suggests that women who do not intend to become pregnant have higher odds of having ANOs. Limited autonomy over reproductive and family planning choices in the patriarchal society of India, might lead to unintended pregnancies. This lack of autonomy may result in inadequate prenatal care and unhealthy practices, increasing the risk of ANOs due to societal expectations and restricted access to healthcare resources. The absence of intended pregnancy may lead to delays in seeking medical attention and adopting unhealthy prenatal practices, ultimately increasing the risk of adverse outcomes for both mother and child.

Birth preparedness is an essential component of safe motherhood programs; a recent study reported lower prevalence of BPCR in India [53]. Various other primary studies have reported a positive correlation between knowledge about all BPCR components

Table 2 Multilevel logistic regression analysis to assess the effect of background characteristics on the likelihood of adverse neonatal outcomes, India, 2019–21

Background characteristics	Model I (individual level)	Model II (Individual + Household level)	Model III (Individual + Household level + Community level)
	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
High risk fertility behavior			
No	Ref	Ref	Ref
Yes	1.02 [1, 1.04]	1.01 [0.99, 1.04]	1.01 [0.98, 1.03]
Mother's educational Status			
Illiterate	Ref	Ref	Ref
Primary	1.04 [1, 1.08]	1.06** [1.01, 1.1]	1.06*** [1.02, 1.11]
Secondary	0.96** [0.93, 0.99]	0.97** [0.93, 1]	1.01 [0.97, 1.04]
Higher	0.85*** [0.82, 0.89]	0.86*** [0.82, 0.9]	0.92*** [0.88, 0.96]
Height of the mother (in cm.)			
< = 150	Ref	Ref	Ref
150–155	0.87*** [0.84, 0.89]	0.87*** [0.84, 0.89]	0.86*** [0.83, 0.88]
> 155	0.81*** [0.79, 0.84]	0.81*** [0.79, 0.84]	0.8*** [0.77, 0.82]
Intention to become pregnant			
Then	Ref	Ref	Ref
Later	1.14*** [1.08, 1.2]	1.11*** [1.05, 1.18]	1.11*** [1.05, 1.18]
No more	1.05 [0.99, 1.1]	1.03 [0.97, 1.09]	1.01 [0.96, 1.08]
ANC registration status			
No	Ref	Ref	Ref
Yes	0.95** [0.91, 0.99]	0.95 [0.91, 1]	0.95** [0.9, 0.99]
Perceived BPCR			
None	Ref	Ref	Ref
At least one	0.97 [0.93, 1.01]	0.98 [0.94, 1.02]	0.97 [0.93, 1.01]
All	0.9*** [0.86, 0.93]	0.91*** [0.87, 0.95]	0.88*** [0.84, 0.92]
Getting medical help for self is problem?			
No	Ref	Ref	Ref
Low	1.02 [0.98, 1.06]	1.02 [0.98, 1.06]	1.03 [0.99, 1.07]
Moderate	1.13*** [1.09, 1.17]	1.13*** [1.09, 1.18]	1.13*** [1.09, 1.18]
High	1.19*** [1.14, 1.23]	1.18*** [1.14, 1.23]	1.2*** [1.15, 1.25]
Perceived quality of antenatal checkups			
None/Some	Ref	Ref	Ref
All	0.96** [0.93, 0.99]	0.97** [0.94, 1]	0.98 [0.95, 1.01]
Experience of complications			
No	Ref	Ref	Ref
Any one	1.02 [0.99, 1.05]	1.02 [0.99, 1.05]	1.02 [0.99, 1.05]
Any two	1.05*** [1.02, 1.08]	1.04** [1.01, 1.07]	1.03** [1, 1.07]
Three & more	1.09*** [1.06, 1.13]	1.07*** [1.04, 1.11]	1.05*** [1.02, 1.09]
Wealth index			
Poorest		Ref	Ref
Poorer		1.08*** [1.04, 1.12]	1.03 [0.99, 1.07]
Middle		0.99 [0.94, 1.03]	0.91*** [0.87, 0.95]
Richer		1.04 [1, 1.09]	0.92*** [0.88, 0.97]
Richest		1.02 [0.96, 1.07]	0.84*** [0.79, 0.89]
Type of cooking fuel			
Unclean fuel		Ref	Ref
Clean fuel		0.98 [0.95, 1.01]	1.03 [0.99, 1.06]

Table 2 (continued)

Background characteristics	Model I (individual level)	Model II (Individual + Household level)	Model III (Individual + Household level + Community level)
	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Media Exposure			
Not at all		Ref	Ref
Less than/at least once		0.94*** [0.92, 0.97]	0.96** [0.93, 0.99]
Caste			
General		Ref	Ref
SC		1.0 [0.96, 1.04]	1.01 [0.97, 1.05]
ST		0.87*** [0.83, 0.91]	0.91*** [0.87, 0.95]
OBC		0.97** [0.94, 1]	1.0 [0.96, 1.03]
Religion			
Hindu		Ref	Ref
Muslim		0.94*** [0.9, 0.97]	0.95** [0.92, 0.99]
Other		0.89*** [0.84, 0.95]	0.92** [0.87, 0.98]
Residential Status			
Urban			Ref
Rural			1.00 [0.97, 1.03]
Maternal community economic status			
High			Ref
Low			0.94*** [0.91, 0.97]
Maternal community education status			
High			Ref
Low			1.04 [1, 1.07]
Region			
Southern			Ref
Central			1.33*** [1.28, 1.39]
North			1.56*** [1.48, 1.65]
Eastern			1.00 [0.96, 1.05]
Northeastern			0.81*** [0.75, 0.88]
Western			1.26*** [1.21, 1.32]
Number of Observation	172,336	154,610	154,610

Authors calculation

Blank cells indicate variables not considered for analysis

$p < 0.05$**; $p < 0.001$***; not significant – no star sign [p value result based on Multilevel logistic regression results]

Table 3 Variance estimates across families, communities and districts, and intra-class correlation coefficients (ICCs) for the multilevel models of adverse neonatal outcome

Random effect parameters	Model 0 (Null Model)	Model III (Individual + Household level + Community level)
District ICC	6.2%	4.7%
Community (PSU) + District ICC	19.7%	18.8%
Household + Community (PSU) + District ICC	31.3%	30.9%
District random variance (SE)	0.0037 [0.05; 0.07]	0.0031 [0.04; 0.05]
Community (PSU) random variance (SE)	0.0045 [0.19; 0.21]	0.0044 [0.18; 0.20]
Household random variance (SE)	0.0165 [0.28; 0.35]	0.0194 [0.27; 0.35]

Result of LR test: [$N = 1,54,610$ || LR Chi2(8) = 158.8 || Prob > chi2 = < 0.000 || AIC = 167,268.8 || BIC = 167,676.7]

and lower risk of adverse outcomes [49]. BPCR strategies usually include preparing for emergencies and building support networks. These help women to be ready to handle any complication during childbirth or pregnancy. Its knowledge empowers individuals to recognize warning signs and seek timely healthcare interventions, thus minimizing the likelihood of complications escalating into adverse outcomes. Also, effective birth preparedness ensures access to skilled birth attendants, appropriate medical facilities, and necessary resources, optimizing the chances of safe delivery and postnatal care. Not only women, but it's also the family as a whole that should be the focus for BPCR.

ANOs have been defined differently by different researchers [23, 63–67]. While preterm birth, LBW and early NMR have been consistent inclusions, there are factors such as congenital malformations, post term birth, maternal mortality, neonatal mortality beyond 7 days variedly reported by several studies. Hence this precludes comparison between studies.

Another finding of this study was that women from Schedule tribes have a lower risk of having adverse outcomes. This lower risk can be attributed to various socio-cultural and healthcare factors specific to these populations [61]. Schedule tribe communities often have strong social support systems and traditional practices that prioritize maternal and child health, which could contribute to better outcomes. Additionally, targeted healthcare interventions and initiatives tailored to these marginalized populations may also play a role in mitigating adverse outcomes.

Our study also revealed that there is a significant difference in adverse neonatal outcomes among families, communities, and districts. This implies that the risk of adverse outcomes varies from one family to another, from one community to another, and from one district to another. The study further indicates that after including selected variables in our analysis, the differences in adverse neonatal outcomes across these levels decreased. This reduction in variability suggests that the included variables partly explain the observed differences, indicating that by addressing these factors, it's possible to reduce the disparities in neonatal outcomes among different families, communities, and districts. This finding is crucial for public health, as it points to the potential for targeted interventions to improve neonatal outcomes by addressing specific risk factors at each level.

To concentrate on the increasing trend of ANOs in India, comprehensive programs to promote birth preparedness and complication readiness are required. Additionally, there is need to institute a mechanism for generating knowledge amongst women to protect them from unwanted pregnancies and later adverse outcomes.

ANO could be defined by encompassing several factors other than preterm births, LBW, and early neonatal mortality such as small for gestational age, low APGAR score, birth defects, late neonatal deaths, and so on. We restricted ourselves to these three conditions based on the availability of publicly available large-scale data. Caution should therefore be exercised while comparing the findings of this study with similar ones. Despite this limitation, this study is one of its kind where we have attempted to explore determinants of selected adverse neonatal outcomes using data from a large scale nationally representative sample survey. For analyzing the determinants, we have included information from recently delivered women having 174,947 live births to capture variables from diverse set of categories like medical and health seeking variables also. The findings underscore the growing concerns around selected adverse outcomes. Besides, it highlights an important parameter of birth preparedness and complication readiness, and several other community level factors that are rarely discussed in the context of adverse outcomes. Use of multilevel modeling also provides methodological level strengths. Some of the key limitations despite having various methodological and conceptual strengths relate to the variable selection and development of composite index. We planned to include stillbirth and miscarriages also in our study, however due to data limitations we could not do that. Nutritional level variables were also not analyzed in this study.

Conclusion and Recommendation

The study underscores that specific adverse neonatal outcomes in India has shown an increase, prompting significant concern. Factors such as low literacy rates, belonging to poor wealth, lack of preparedness for childbirth or complications, and having no intentions regarding the current pregnancy have been implicated as contributory factors. There is need to institute a mechanism for generating knowledge amongst women to protect them from unwanted pregnancies and later adverse outcomes.

Abbreviations

ANO	Adverse neonatal Outcome
DHS	Demographic and Health Survey
NFHS	National Family Health Survey
LBW	Low birth weight.
IFA	Iron folic acid supplementation
PTB	Preterm birth
BPCR	Birth preparedness and complication readiness
HRFB	High risk fertility behavior
ANC	Antenatal Checkup

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12884-025-07448-9.

Supplementary Material 1.

Acknowledgements
None.

Authors' contributions
The authors confirm contribution to the paper as follows: study conception and design: AKP, BTM, SBN; data collection: AKP, BTM; Literature review: AKP, DG; analysis and interpretation of results: AKP, BTM, AB; draft manuscript preparation: AKP, DG, BTM. All authors (AKP, BTM, DG, AB, DAW, SS, SBN) reviewed the results and approved the final version of the manuscript.

Funding
None.

Data availability
The data used for this study has been downloaded from DHS data program portal after the prior registration and permission. There are no identifiers in the data which is available in the public domain thus has no ethical implication.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not Applicable.

Competing interests
The authors declare no competing interests. SBN is a member of the Editorial board for the BMC Pregnancy and Childbirth.

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Received: 13 May 2024 Accepted: 10 March 2025
Published online: 31 March 2025

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