

Determinants of Delayed Vaccination Among Children in EAG and Non-EAG States of India: Using NFHS-5

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Abstract—

Objective: This study aims to estimate the proportion of children aged 12–24 months who experienced delayed vaccination and to identify the factors associated with such delays in EAG and non-EAG states, including only those children whose vaccination dates were available on the mother and Child Protection (MCP) card.

Methods: We utilized individual-level data from the 5th round of the National Family Health Survey (NFHS-5), conducted during 2019–2021, available from the Demographic and Health Survey (DHS) program. The primary outcome of this study was prevalence of delayed vaccination for BCG, at least 1 dose of DPT and Measles separately for all states/UTs of India. Delay in vaccination for each vaccine was calculated from right age for scheduled vaccination and the date of administered scheduled vaccines. We have considered the National immunization schedule as our reference point for calculation of delay. We estimated the number and proportion of children with delayed vaccination for each vaccine and used multivariable logistic regression to explore associated factors.

Results: Among children 12–24 months, delays were observed for BCG (15.3%), at least one dose of DPT (97.3%) and measles (14.2%). In EAG states, Muslim children were more likely to have delayed BCG (AOR=1.55) and measles (AOR=1.46), but less likely for DPT (AOR=0.64). In non-EAG states, Scheduled tribe children showed higher odds of delay for BCG (AOR=1.67) and measles (AOR=1.37), but lower for DPT (AOR=0.51). Wealthier families in EAG states had lower risk, while in non-EAG states, rural residence, higher maternal education, and higher birth order increased odds of delay. Working mothers reduced risk in EAG states.

Conclusion: Despite high coverage, vaccine timeliness remains a challenge. Program priorities should focus on ensuring timely vaccination, particularly among disadvantaged groups such as Muslim households, Scheduled tribe, rural families, higher birth -order children, and those with less educated mothers in India.

Keywords: Delayed vaccination, Child & maternal health, Child immunization, EAG-non EAG States, Adjusted odds ratio (AOR)

I. INTRODUCTION

Timely childhood vaccination is a critical component of effective immunization programmes, ensuring that children are protected against vaccine-preventable diseases during periods of highest biological vulnerability. While vaccination coverage remains the most widely used indicator for assessing immunization programme performance, it does not capture whether vaccines are administered within the recommended age intervals. Increasing evidence suggests that delayed vaccination defined as receipt of vaccines later than the age specified in national immunization schedules undermines the protective benefits of immunization and poses a significant public health concern, particularly in low- and middle-income countries (LMICs) [1–3].

Vaccines confer optimal protection when administered according to schedule. Delays in vaccination prolong children's exposure to infectious diseases, increase the risk of severe illness and death, and may contribute to outbreaks, especially for highly transmissible diseases such as measles and pertussis [4,5]. Even in settings where final vaccination coverage is high, widespread delays can result in immunity gaps during early childhood, thereby reducing both individual-level and population-level protection [6,7]. Consequently, vaccination timeliness is increasingly recognized as a crucial dimension of immunization programme effectiveness rather than a secondary outcome [3,8].

Globally, progress in routine immunization has slowed in recent years. According to the World Health Organization (WHO) and UNICEF, coverage with the third dose of diphtheria–tetanus–pertussis vaccine (DTP3) stagnated at around 84–85% between 2019 and 2024 [1,9]. In 2023, an estimated 14.5 million children were classified as “zero-dose,” having received no routine vaccinations, while millions more initiated vaccination but experienced delays or incomplete schedules [9,10]. These patterns indicate that challenges in immunization delivery extend beyond outright non-coverage to include problems related to timing and continuity of care.



Delayed vaccination arises from a complex interaction of demand-side and supply-side factors. Demand-side determinants include caregivers' knowledge and awareness of vaccination schedules, perceptions of disease risk, cultural beliefs, competing household responsibilities, and vaccine hesitancy defined as delay in acceptance or refusal of vaccines despite availability [11,12]. Supply-side constraints include vaccine stockouts, limited outreach services, inconvenient clinic hours, shortages of trained health workers, and geographic barriers to accessing health facilities [10,13]. Importantly, these factors often operate simultaneously, leading to repeated postponements across successive vaccine doses.

In India, the Universal Immunization Programme (UIP) provides free vaccines against multiple childhood diseases and represents one of the largest public health programmes in the world. National surveys indicate substantial improvements in overall vaccination coverage over time; full immunization among children aged 12–23 months increased from 62% in 2015–16 to 77% in 2019–21 [14,15]. However, these estimates focus primarily on whether vaccines were ever received and provide limited insight into whether doses were administered at the recommended ages. Evidence from previous studies using National Family Health Survey (NFHS) data suggests that delays in BCG, DPT, polio, and measles vaccination remain common and socially patterned, with higher delays observed among socioeconomically disadvantaged groups and in specific regions [7,16–18].

Assessing delayed vaccination offers important insights into immunization programme performance that are not captured by coverage indicators alone. Analyses of timeliness help identify vulnerable populations, reveal hidden inequalities, and inform targeted interventions such as reminder systems, caregiver education, improved outreach planning, and health system strengthening [3,6,12]. This focus aligns with global priorities articulated in Immunization Agenda 2030, which emphasizes equitable access and timely delivery of vaccines for all children [2].

Against this backdrop, the present study examines the prevalence and socioeconomic determinants of delayed vaccination among children aged 12–24 months in India. Focusing on delays in BCG, at least one dose of DPT, oral polio, and measles vaccines, this study aims to contribute evidence that can support more responsive and equitable immunization strategies, ensuring that children are not only vaccinated but vaccinated on time.

II. METHODOLOGY

Data Source

The analysis utilized individual-level data from the fifth round of the National Family Health Survey (NFHS-5, 2019–21), a nationally representative cross-sectional survey implemented by the Ministry of Health and Family Welfare (MoHFW), Government of India. The International Institute for Population Sciences (IIPS), Mumbai, functioned as the nodal agency. Fieldwork was carried out in two phases: June 2019–January 2020 (Phase I: 17 states, 5 union territories) and January 2020–April 2021 (Phase II: 11 states, 3 union territories). NFHS-5 interviewed 636,699 households, including 724,115 women and 101,839 men, the survey followed a stratified two-stage sampling design. In rural areas, villages were selected as primary sampling units (PSUs), while in urban areas, Census Enumeration Blocks (CEBs) served as PSUs. Within each PSU, households were chosen through systematic random sampling [15]. For this analysis, we utilized the children recode dataset from the Demographic and Health Surveys (DHS) program [19]. Data on vaccination status were derived from the mother and Child Protection (MCP) card/health card. To ensure accuracy, only children aged 12–24 months with recorded vaccination dates on the MCP card were included. Children with immunization data based only on maternal recall or without exact vaccination dates were excluded [20].

Variables

A child is considered fully immunized upon receiving one dose of BCG, three doses of DPT, three doses of polio, and one dose of measles vaccine. This study examines delayed vaccination, defined as the receipt of any vaccine dose later than the recommended age in the national immunization schedule [21]. For each vaccine, we estimated the proportion of children who experienced such delays. Date of birth and age at vaccination (for individual vaccine dose) was calculated in century day code format [20]. Delay in vaccination was calculated from right age for scheduled vaccination and the date of administered scheduled vaccines. We have considered the National immunization schedule as our reference point for calculation of delay as children receiving vaccination post birth for BCG, after completion of 6 week for DPT-1, 10 weeks for DPT-2, 14 weeks for DPT-3 and 9–12 months for Measles [22]. Since in NFHS data we noticed that when the first dose of the DPT vaccine is delayed, the second and third doses are also typically administered later than the recommended schedule; therefore, children experiencing a delay in any DPT dose are classified as having a DPT delay.



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Since the DPT and oral polio vaccines are administered on the same scheduled dates under India's national immunization schedule and exhibited only minimal differences in delay patterns, this study considers delay in DPT vaccination as a proxy indicator. Polio vaccination was therefore excluded from the analysis to avoid redundancy and ensure analytical parsimony. Covariates are grouped as: Socio-demographic: religion, caste, residence, wealth quintile. Maternal: education, age. Child: sex and birth order.

III. STATISTICAL ANALYSIS

Prevalence of delayed vaccination was estimated at national level and separately for non-EAG and EAG states. Univariate analyses examined associations between explanatory variables and vaccination delays.

After that, multivariable logistic regression models were used to estimate the risk associated with covariates for delayed BCG, at least one dose of DPT and measles.

All studies were completed using IBM SPSS Statistics 25, accounting for sampling weights and clustering. R Software (R version 4.5.2) is used for diagram. A p -value <0.05 was considered statistically significant.

IV. RESULTS

According to Figure 1, the analytical sample comprised 38,158 children for BCG, 34,768 children for DPT (considering at least one dose), and 28,308 children for measles vaccination. The analysis was restricted to children with complete vaccination records and clearly documented dates on the health card, ensuring accurate assessment of vaccination delay. In Table 1 findings revealed that delayed vaccination occurred in 15.3% of children for BCG, 97.3% for at least one dose of DPT and 11.4% for measles among children aged 12–24 months.

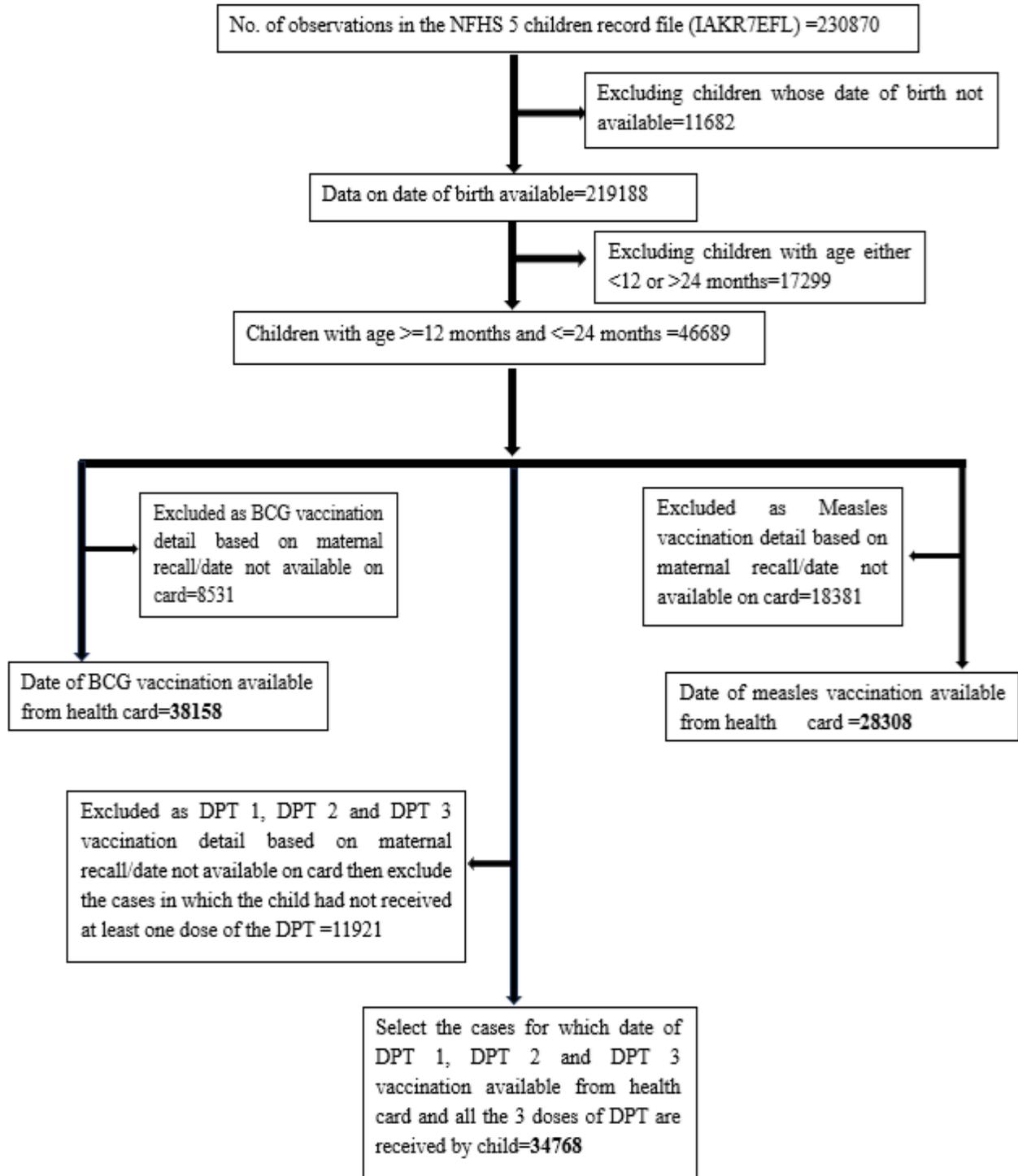


Figure 1. Flowchart of data selection and exclusion process from the NFHS-5 children recode file used in the present study.

Table1:
Distribution of delayed and non-delayed vaccinations in India (2019-2020)

| Vaccine | Total no. of children (having health card) received vaccine | Delay N (%) | Non -Delay N (%) |
|---------------------------------|---|-------------|------------------|
| BCG | 38158 | 5839(15.3) | 32319(84.7) |
| Measles | 28308 | 3224(11.4) | 25083(88.6) |
| DPT/Polio 1st dose | 34768 | 31850(91.6) | 2918(8.4) |
| DPT/Polio 2nd dose | 34768 | 32916(94.7) | 1851(5.3) |
| DPT/Polio 3rd dose | 34768 | 33475(96.3) | 1293(3.7) |
| At least one dose of DPT | 34768 | 33823(97.3) | 944(2.7) |

Table 2 and figure 2 reveal notable disparities in vaccination delays across Indian states, underscoring the need for targeted interventions in regions with particularly high prevalence, such as Manipur, Tripura, and Uttar Pradesh.

Table 2:
Prevalence of delayed vaccination in different States/UTs of India for children (10 -23) months of age. (NFHS 5, 2019-2021).

| State | BCG delayed | At least 1 dose of DPT delayed | Measles delayed |
|-------------------|-------------|--------------------------------|-----------------|
| Arunachal Pradesh | 18.5 | 93.5 | 6.9 |
| Assam | 31 | 96.8 | 10.3 |
| Chandigarh | 7.2 | 96.5 | 8.8 |
| Karnataka | 10.9 | 98 | 8 |
| Manipur | 66.9 | 99.5 | 9.7 |
| Meghalaya | 31.9 | 97.9 | 19.6 |
| Mizoram | 34.4 | 93.4 | 8.4 |
| Nagaland | 33.8 | 97.5 | 12.5 |
| Punjab | 9.3 | 97.2 | 8.6 |
| Rajasthan | 9.8 | 93.8 | 4 |
| Sikkim | 2.4 | 87 | 5.6 |
| Tripura | 37.8 | 95 | 9.7 |
| Uttarakhand | 16.4 | 98.1 | 6.4 |
| Telangana | 8.9 | 97.8 | 5.1 |
| Bihar | 18.1 | 98.1 | 17.5 |

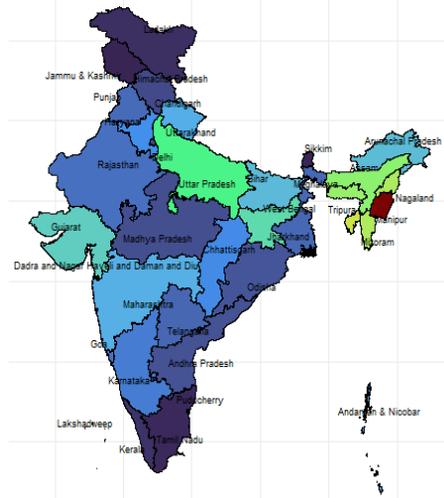


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| | | | |
|------------------------------|------|------|------|
| Kerala | 3.8 | 98.6 | 12.1 |
| Madhya Pradesh | 6.6 | 97.1 | 10.6 |
| Andaman & Nicobar | 13.9 | 99.2 | 0 |
| Gujarat | 20.9 | 97 | 8.5 |
| Lakshadweep | 4 | 100 | 0 |
| Odisha | 7.2 | 98.5 | 6.8 |
| ¹ D & N and D & D | 11.2 | 98.2 | 6.1 |
| Jammu & Kashmir | 2.3 | 95.6 | 4.4 |
| Chhattisgarh | 12.3 | 97.2 | 6.9 |
| Delhi | 6.2 | 99.1 | 8.2 |
| Goa | 9.8 | 100 | 13 |
| Haryana | 12.6 | 98.7 | 5.4 |
| Himachal Pradesh | 6.1 | 99.3 | 2.8 |
| Jharkhand | 22.7 | 95 | 16.7 |
| Tamil Nadu | 2.8 | 97.8 | 4.6 |
| Uttar Pradesh | 26.5 | 96.7 | 19.4 |
| West Bengal | 9.1 | 98.1 | 5.5 |
| Andhra Pradesh | 6.9 | 98.3 | 5.2 |
| Puducherry | 0.4 | 99.9 | 4.8 |
| Maharashtra | 16.6 | 97.6 | 17.6 |
| Ladakh | 3.4 | 92.1 | 3 |

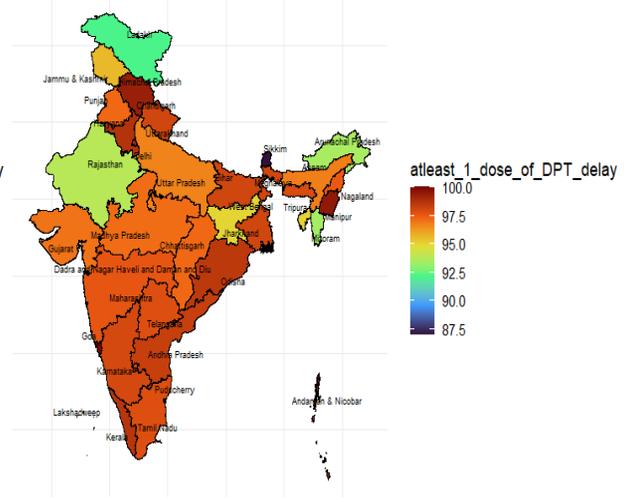
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Delay in BCG vaccination in state/UTs



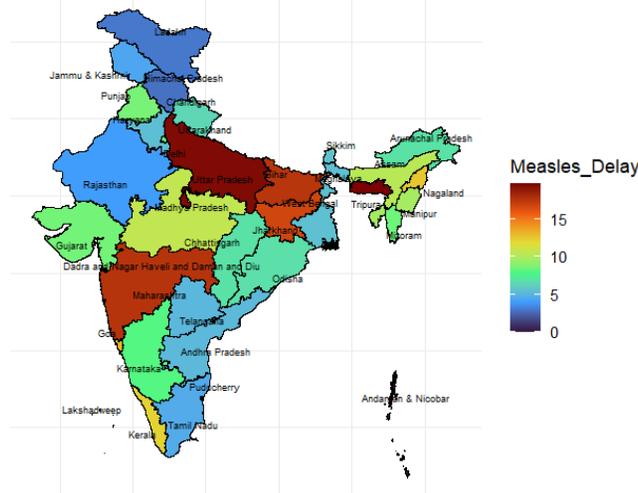
(a)

Delay in at least 1 dose of DPT vaccination in state/UTs



(b)

Delay in Measles vaccination in state/UTs



(c)

Figure 2: States/UTs wise prevalence of late vaccination for (a) BCG, (b) DPT, and (c) Measles respectively in India.

Figure 2(a) shows that the prevalence of delayed BCG vaccination was maximum in Manipur (66.9%) and lowest in Puducherry (0.4%). As presented in Figure 2(b), Goa and Lakshadweep recorded the highest prevalence of delayed administration of at least one DPT dose (100% each), while Sikkim had the lowest (87%).

Similarly, Figure 2(d) highlights that delayed measles vaccination was most common in Meghalaya (19.6%), while Andaman & Nicobar Islands and Lakshadweep reported no delays (0%). These findings demonstrate wide regional variation in delayed vaccination across the country.



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Such differences are likely influenced by disparities in healthcare infrastructure, service delivery, geographic accessibility, parental awareness, and broader socio-economic factors.

Table 3 presents the number (N) and percentage (%) of children experiencing delayed vaccination for BCG, Measles, and at least one dose of DPT, disaggregated by socio-demographic, economic, and maternal characteristics in non-EAG and EAG states. In non-EAG states, delays were highest among Muslim children (16.3%), followed by other religions (13.1%) and Hindus (11.1%), whereas in EAG states delays were substantially higher, particularly among Muslims (24.6%), followed by other religions (18.0%) and Hindus (17.1%). Marked caste differentials were observed: Scheduled Tribe children showed the highest delay in non-EAG states (17.7%), while Scheduled Castes were most disadvantaged in EAG states (19.9%). A clear wealth gradient was evident, with delays declining from the poorest to the richest households in both regions (non-EAG: 16.3% to 7.5%; EAG: 22.4% to 14.5%), indicating pronounced socioeconomic inequality. Rural children experienced higher delays than urban children in both regions, particularly in non-EAG states, though absolute rural delays remained high in EAG states (18.7%). Maternal education showed a strong protective effect: in non-EAG states, delays declined from 18.5% among uneducated mothers to 6.5% among those with higher education, while in EAG states delays remained elevated even among highly educated mothers (16.3%). Delays increased with birth order in both regions, reaching over 23% among fourth-or-higher order births. Gender differences were minimal, with only slightly higher delays among females in non-EAG states. BCG vaccination delays were consistently higher in EAG than non-EAG states across all sociodemographic groups.

In non-EAG states, Measles delays were higher among children from other religions (9.7%) and Muslims (7.9%) compared with Hindus (6.2%), while in EAG states Muslim children experienced the highest delay (16.2%). Caste disparities persisted, with Scheduled Castes most disadvantaged in EAG states (14.3%). Wealth-related differences were modest in non-EAG states but more pronounced in EAG states, where delays declined from 14.5% among the poorest to 10.1% among the richest. Rural–urban differences were small, and in EAG states both rural and urban children experienced similarly high delays (~12%). Maternal education was strongly associated with timely vaccination in EAG states, with delays declining from 14.4% among uneducated mothers to 9.8% among those with higher education. Delays increased with maternal age and birth order in both regions. Female children experienced higher delays than males in non-EAG states, while no gender difference was observed in EAG states. Measles vaccination delays were lower than BCG delays but exhibited persistent regional and socioeconomic inequalities.

In non-EAG states, delays were marginally higher among Hindu (98.1%) and other-religion children (98.0%) than Muslims (97.3%), while in EAG states delays were slightly lower overall, particularly among Muslims (95.4%) and other religions (94.5%). Caste and wealth differentials were statistically significant but small in magnitude, with delays exceeding 96% across all groups. Rural children experienced slightly higher delays than urban children in both regions. Educational gradients were weak, maternal age showed no meaningful association, and only minor differences were observed by birth order and gender. Overall, DPT delay appeared less sensitive to socioeconomic disadvantage compared with BCG and measles vaccines. DPT vaccination delay was universally high (>96%) in both regions and showed limited socioeconomic variation.

Table 3:
Distribution of BCG Delay with demographic characteristics in EAG and Non EAG states.

| Variables | BCG delay | | | |
|--------------------------------------|---------------|-----------------|-----------|-----------------|
| | Non EAG state | | EAG state | |
| | N | % (95% CI) | N | % (95% CI) |
| Religion* | | | | |
| Hindu | 1502 | 11.2(10.7,11.8) | 2939 | 17.1(16.5,17.6) |
| Muslim | 540 | 16.2(15,17.5) | 619 | 24.5(22.8,26.1) |
| Others | 182 | 13.1(11.4,15) | 56 | 18.1(14,22.6) |
| Caste* | | | | |
| Schedule caste | 390 | 9.8(8.9,10.8) | 952 | 19.5(18.4,20.6) |
| Schedule tribe | 308 | 17.8(16,19.6) | 298 | 14(12.5,15.5) |
| OBC | 759 | 11.2(10.5,12) | 1762 | 18(17.2,18.7) |
| Others | 768 | 13.6(12.7,14.5) | 602 | 18.6(17.3,20) |
| Wealth index within state* | | | | |
| Poorest | 576 | 16.3(15.2,17.6) | 907 | 22.1(20.8,23.4) |
| Poorer | 556 | 14(12.9,15.1) | 770 | 18(16.9,19.2) |
| Middle | 418 | 10.8(9.9,11.8) | 751 | 18.3(17.1,19.5) |
| Richer | 423 | 11.3(10.3,12.4) | 686 | 16.5(15.4,17.6) |
| Richest | 252 | 8.4(7.4,9.4) | 500 | 14.7(13.5,15.9) |
| Type of place of residence* | | | | |
| Urban | 605 | 9.4(8.7,10.1) | 542 | 14.6(13.5,15.8) |
| Rural | 1619 | 13.9(13.3,14.5) | 3072 | 18.8(18.2,19.4) |
| Highest educational level* | | | | |
| No education | 286 | 17.8(15.9,19.7) | 1123 | 22.4(21.2,23.5) |
| Primary | 296 | 17.4(15.7,19.3) | 500 | 18.9(17.4,20.4) |
| Secondary | 1401 | 12.8(12.2,13.5) | 1531 | 15.9(15.2,16.7) |
| Higher | 241 | 6.3(5.5,7) | 460 | 16.6(15.2,18) |
| mother age group* | | | | |
| 15-24 | 949 | 13(12.3,13.8) | 1444 | 17.5(16.7,18.3) |
| 25-34 | 1125 | 11.5(10.9,12.2) | 1937 | 18.2(17.5,18.9) |
| 35-44 | 137 | 13.4(11.5,15.6) | 227 | 20.1(17.9,22.5) |
| 45+ | 14 | 43.8(27.7,60.9) | 7 | 23.5(11.9,42.9) |
| Respondent currently working* | | | | |
| No | 271 | 11.8(10.6,13.2) | 477 | 17.5(16.1,19) |
| Yes | 52 | 11.1(8.5,14.3) | 66 | 17.8(14.2,21.9) |
| Birth Order* | | | | |
| 1 | 929 | 11.3(10.7,12) | 1117 | 15.4(14.5,16.2) |
| 2 | 734 | 10.8(10.1,11.6) | 1180 | 18.3(17.4,19.3) |
| 3 | 332 | 15.7(14.2,17.3) | 649 | 19(17.7,20.3) |

| | | | | |
|--------------------------------------|------|-----------------|------|-----------------|
| 4 or more | 229 | 23.1(20.6,25.8) | 668 | 22.9(21.4,24.4) |
| Sex of child* | | | | |
| Male | 1129 | 11.8(11.2,12.5) | 1888 | 18.2(17.5,18.9) |
| Female | 1096 | 12.8(12.1,13.5) | 1726 | 17.8(17.1,18.6) |
| MEASLES delay | | | | |
| Religion* | | | | |
| Hindu | 779 | 7.7(7.2,8.2) | 1766 | 13.7(13.1,14.3) |
| Muslim | 216 | 9.3(8.2,10.6) | 328 | 18.5(16.8,20.4) |
| Others | 108 | 11.5(9.5,13.6) | 27 | 10.9(7.3,15) |
| Caste* | | | | |
| Schedule caste | 216 | 7(6.1,8) | 607 | 16.6(15.4,17.8) |
| Schedule tribe | 108 | 9.6(8,11.4) | 183 | 11.3(9.8,12.9) |
| OBC | 377 | 7.4(6.7,8.2) | 1023 | 14.1(13.4,15) |
| Others | 403 | 9.8(8.9,10.8) | 308 | 12.9(11.6,14.2) |
| Wealth index within state* | | | | |
| Poorest | 257 | 10.1(9,11.3) | 489 | 17.1(15.8,18.6) |
| Poorer | 230 | 7.8(6.9,8.8) | 471 | 15.1(13.8,16.4) |
| Middle | 204 | 7.3(6.3,8.3) | 428 | 14(12.8,15.2) |
| Richer | 217 | 7.8(6.9,8.9) | 417 | 13(11.9,14.2) |
| Richest | 195 | 8.5(7.4,9.6) | 317 | 11.9(10.7,13.1) |
| Type of place of residence* | | | | |
| Urban | 447 | 9.3(8.5,10.2) | 389 | 13.9(12.7,15.3) |
| Rural | 656 | 7.6(7.1,8.2) | 1732 | 14.3(13.7,14.9) |
| Highest educational level* | | | | |
| No education | 91 | 8.1(6.6,9.8) | 586 | 16.9(15.7,18.2) |
| Primary | 126 | 10.1(8.5,11.8) | 296 | 15.2(13.7,16.9) |
| Secondary | 671 | 8.3(7.7,8.9) | 997 | 13.5(12.8,14.3) |
| Higher | 215 | 7.3(6.4,8.3) | 243 | 11.4(10.1,12.8) |
| mother age group* | | | | |
| 15-24 | 405 | 7.6(6.9,8.3) | 952 | 15.5(14.6,16.4) |
| 25-34 | 630 | 8.6(8,9.3) | 1055 | 13.3(12.6,14.1) |
| 35-44 | 68 | 9.3(7.4,11.7) | 109 | 13.2(11,15.6) |
| 45+ | 0 | 0(.,.) | 5 | 19.7(8.4,39.8) |
| Respondent currently working* | | | | |
| No | 144 | 8.4(7.2,9.8) | 294 | 14.5(13,16.1) |
| Yes | 25 | 7.2(4.8,10.2) | 37 | 14(10.1,18.5) |
| Birth Order* | | | | |
| 1 | 452 | 7.3(6.7,8) | 729 | 13.2(12.3,14.1) |
| 2 | 425 | 8.5(7.7,9.3) | 636 | 13.2(12.3,14.2) |

| | | | | |
|---------------------------------------|-------|-----------------|-------|-----------------|
| 3 | 139 | 9.1(7.7,10.6) | 414 | 16.4(15,17.9) |
| 4 or more | 86 | 12.7(10.3,15.3) | 342 | 16.6(15,18.3) |
| Sex of child* | | | | |
| Male | 523 | 7.4(6.8,8.1) | 1098 | 14.2(13.4,15) |
| Female | 580 | 9.1(8.5,9.9) | 1024 | 14.2(13.4,15.1) |
| At least one dose of DPT delay | | | | |
| Religion* | | | | |
| Hindu | 12320 | 97.9(97.6,98.1) | 15002 | 97.1(96.8,97.3) |
| Muslim | 2960 | 97.3(96.7,97.8) | 2006 | 95.3(94.4,96.2) |
| Others | 1259 | 97.7(96.8,98.5) | 277 | 94.5(91.5,96.7) |
| Caste* | | | | |
| Schedule caste | 3661 | 98.3(97.9,98.7) | 4249 | 97(96.5,97.5) |
| Schedule tribe | 1522 | 96.7(95.8,97.5) | 1836 | 95.9(95,96.7) |
| OBC | 6267 | 98.2(97.9,98.5) | 8456 | 96.8(96.5,97.2) |
| Others | 5089 | 97.2(96.7,97.6) | 2744 | 97(96.3,97.5) |
| Wealth index within state* | | | | |
| Poorest | 3125 | 97.5(97,98) | 3480 | 96.5(95.9,97.1) |
| Poorer | 3641 | 98.4(98,98.8) | 3629 | 97(96.4,97.5) |
| Middle | 3570 | 98.3(97.8,98.7) | 3568 | 97(96.4,97.5) |
| Richer | 3441 | 97.6(97,98.1) | 3654 | 96.7(96.1,97.3) |
| Richest | 2761 | 96.9(96.2,97.4) | 2954 | 96.8(96.1,97.4) |
| Type of place of residence* | | | | |
| Urban | 5875 | 97.1(96.6,97.5) | 3122 | 96.4(95.7,97) |
| Rural | 10664 | 98.2(97.9,98.4) | 14163 | 96.9(96.6,97.2) |
| Highest educational level* | | | | |
| No education | 1397 | 96.5(95.4,97.3) | 4172 | 96.2(95.6,96.7) |
| Primary | 1537 | 96.9(96,97.7) | 2269 | 96.5(95.7,97.2) |
| Secondary | 10031 | 98.2(97.9,98.4) | 8426 | 97.1(96.7,97.4) |
| Higher | 3575 | 97.6(97.1,98.1) | 2419 | 97.2(96.5,97.8) |
| mother age group* | | | | |
| 15-24 | 6688 | 98.1(97.8,98.4) | 7147 | 97.1(96.7,97.4) |
| 25-34 | 8911 | 97.5(97.2,97.8) | 9177 | 96.6(96.3,97) |
| 35-44 | 909 | 98.1(97,98.8) | 936 | 96.5(95.2,97.5) |
| 45+ | 30 | 98.3(92,100) | 25 | 96.9(83.4,99.6) |
| Respondent currently working* | | | | |
| No | 2077 | 97.7(97,98.3) | 2350 | 96.7(95.9,97.4) |
| Yes | 422 | 98.4(96.8,99.3) | 314 | 93.9(91.1,96.2) |
| Birth Order* | | | | |
| 1 | 7552 | 97.7(97.4,98) | 6416 | 97.1(96.7,97.5) |

| | | | | |
|----------------------|------|-----------------|------|-----------------|
| 2 | 6226 | 98(97.6,98.3) | 5514 | 96.8(96.3,97.3) |
| 3 | 1899 | 97.5(96.7,98.1) | 2914 | 96.3(95.6,97) |
| 4 or more | 861 | 97.8(96.6,98.6) | 2441 | 96.6(95.8,97.2) |
| Sex of child* | | | | |
| Male | 8762 | 97.9(97.6,98.2) | 8959 | 96.7(96.3,97) |
| Female | 7776 | 97.7(97.3,98) | 8326 | 97(96.6,97.3) |

* *P*-value <0.05 for 5% level of significance.

Table 4 presents logistic regression results examining factors related with delays in BCG and Measles vaccination in non-EAG and EAG states. Religion was a strong determinant. Muslim children faced significantly higher odds of BCG delay in both EAG (AOR 1.55; CI [1.39–1.73]) and non-EAG states (AOR 1.27; CI [1.12–1.42]). Measles delay was also higher among Muslims in EAG (AOR 1.46). Children from other religions showed increased risk in non-EAG states for both BCG (AOR 1.19) and Measles (AOR 1.60). Caste patterns varied by region. In EAG states, Scheduled Tribes had lower odds of delay for both vaccines, while in non-EAG states they had higher odds.

“Other” caste groups in non-EAG states also showed significant delays (BCG AOR 1.44; Measles AOR 1.5). Wealth reduced delays, especially in EAG states, where richer households had consistently lower odds. Rural residence increased BCG delays in both areas but was linked to lower Measles delays in non-EAG states. Maternal education showed mixed effects. In EAG states, primary and secondary education reduced BCG delays, while in non-EAG states higher education strongly improved BCG timeliness. Higher birth order consistently increased delays, while gender differences were minor, with slightly higher Measles delays among girls in EAG states.

Table 4:
Logistic regression estimates for factors related with delayed BCG and Measles vaccination in infants aged 10–23 months across EAG and non-EAG states of India (NFHS-5, 2019–21).

| Variables | BCG | | MEASLES | |
|---|-------------------|-------------------|-------------------|-------------------|
| | NON EAG State | EAG State | NON EAG State | EAG State |
| | AOR (95% CI) | AOR (95% CI) | AOR (95% CI) | AOR (95% CI) |
| Religion (ref: Hindu) | | | | |
| Muslim | 1.27(1.12,1.43) * | 1.55(1.39,1.73) * | 0.99(0.83,1.18) | 1.46(1.27,1.68) * |
| Others | 1.19(1,1.41) * | 1.29(0.95,1.74) | 1.6(1.29,1.99) * | 0.89(0.59,1.34) |
| Caste (ref: Schedule caste) | | | | |
| Schedule tribe | 1.67(1.42,1.97) * | 0.61(0.53,0.71) * | 1.37(1.07,1.75) * | 0.62(0.51,0.74) * |
| OBC | 1.28(1.12,1.46) * | 0.92(0.84,1) | 1.16(0.97,1.39) | 0.85(0.76,0.95) * |
| Others | 1.44(1.25,1.67) * | 0.97(0.86,1.1) | 1.55(1.28,1.87) * | 0.78(0.66,0.91) * |
| Wealth index within state (ref: Poorest) | | | | |
| Poorer | 0.97(0.85,1.1) | 0.79(0.7,0.88) * | 0.77(0.64,0.93) * | 0.85(0.74,0.98) * |
| Middle | 0.8(0.69,0.92) * | 0.82(0.73,0.92) * | 0.67(0.55,0.82) * | 0.78(0.68,0.91) * |
| Richer | 0.96(0.82,1.11) | 0.73(0.65,0.83) * | 0.71(0.57,0.88) * | 0.71(0.61,0.84) * |
| Richest | 0.87(0.72,1.05) | 0.68(0.59,0.79) * | 0.73(0.57,0.93) * | 0.66(0.55,0.8) * |

| Type of place of residence (ref: Urban) | | | | |
|--|-------------------|-------------------|-------------------|-------------------|
| Rural | 1.33(1.19,1.49) * | 1.29(1.15,1.44) * | 0.73(0.63,0.84) * | 0.91(0.79,1.04) |
| Highest Education Level (ref: No education) | | | | |
| Primary | 1.08(0.9,1.3) | 0.86(0.76,0.97) * | 1.41(1.06,1.88) * | 0.93(0.8,1.08) |
| Secondary | 0.87(0.74,1.01) | 0.79(0.72,0.87) * | 1.32(1.03,1.69) * | 0.9(0.79,1.02) |
| Higher | 0.45(0.36,0.55) * | 0.95(0.83,1.1) | 1.14(0.85,1.53) | 0.82(0.68,0.99) * |
| Respondent currently working (ref: no) | | | | |
| Yes | 0.64(0.93,0.68) | 1.02(0.77,1.36) | 0.84(0.54,1.30) | 0.96(0.66,1.39) |
| Birth Order (ref: 1) | | | | |
| 2 | 0.88(0.79,0.98) * | 1.22(1.11,1.33) * | 1.14(1,1.32) | 0.97(0.87,1.09) |
| 3 | 1.19(1.03,1.37) * | 1.16(1.04,1.3) * | 1.25(1.01,1.53) * | 1.16(1.02,1.33) * |
| 4 or more | 1.66(1.39,1.98) * | 1.33(1.18,1.49) * | 1.69(1.3,2.22) * | 1.08(0.93,1.25) |
| Sex of child (ref: male) | | | | |
| Female | 1.09(1,1.2) * | 0.98(0.91,1.06) | 1.26(1.11,1.42) * | 1.01(0.92,1.1) |

* *P*-value <0.05 for 5% level of significance, AOR (Adjusted odds ratio)

Table 5 presents logistic regression findings on factors linked to delays in DPT vaccinations across EAG and non-EAG states. Religion emerged as an important factor. In EAG states, Muslim children had significantly lower odds of

delay for DPT (OR=0.63) as compared to Hindus, while differences were not significant in non-EAG states. Children from other religions also showed reduced odds in EAG states, but no significant effects in non-EAG states.

Table 5:
Logistic regression estimates of predictors for delayed DPT vaccination among infants aged 10–23 months across non-EAG and EAG states (NFHS-5, 2019–21).

| Socio-demographic characteristics | DPT | |
|--|---------------------|---------------------|
| | NON EAG State | EAG State |
| | Odds ratio (95% CI) | Odds ratio (95% CI) |
| Religion (ref: Hindu) | | |
| Muslim | 0.84(0.64,1.11) | 0.64(0.5,0.81)* |
| Others | 0.94(0.64,1.39) | 0.62(0.37,1.06) |
| Caste (ref: Schedule caste) | | |
| Schedule tribe | 0.51(0.35,0.74) * | 0.75(0.56,1.01) |
| OBC | 1.01(0.73,1.39) | 0.99(0.79,1.23) |
| Others | 0.69(0.5,0.96) * | 1.09(0.81,1.46) |
| Wealth index within state (ref: Poorest) | | |
| Poorer | 1.36(0.95,1.94) | 1.08(0.83,1.4) |
| Middle | 1.19(0.83,1.71) | 1.06(0.8,1.39) |
| Richer | 0.88(0.61,1.25) | 0.96(0.73,1.28) |
| Richest | 0.7(0.47,1.04) | 0.99(0.7,1.39) |
| Type of place of residence (ref: Urban) | | |
| Rural | 1.54(1.22,1.95)* | 1.18(0.93,1.5) |
| Highest Education Level (ref: No education) | | |
| Primary | 1.14(0.76,1.72) | 1.08(0.82,1.41) |
| Secondary | 2.13(1.5,3.02)* | 1.26(1.01,1.57)* |
| Higher | 2.1(1.37,3.2)* | 1.3(0.93,1.81) |
| Respondent currently working (ref: no) | | |
| Yes | 1.47(0.65,3.31) | 0.53(0.32,0.87)* |
| Birth Order (ref: 1) | | |
| 2 | 1.14(0.9,1.43) | 0.93(0.76,1.14) |
| 3 | 0.99(0.71,1.39) | 0.85(0.67,1.09) |
| 4 or more | 1.49(0.9,2.48) | 0.99(0.75,1.3) |
| Sex of child (ref: male) | | |
| Female | 0.91(0.74,1.12) | 1.1(0.93,1.31) |

* P- value <0.05 for 5% level of significance, AOR (Adjusted odds ratio)



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Caste patterns showed that Scheduled Tribes in non-EAG states had significantly lower odds of delay (DPT OR=0.51), while no differences were observed in EAG states. “Other” caste children in non-EAG states also showed reduced delays for DPT (OR=0.69). Wealth effects were inconsistent. Richest households had lower odds of DPT delays. Rural residence significantly increased risks in non-EAG states (DPT OR=1.54), but not in EAG states. Maternal education in non-EAG states showed an unusual pattern: secondary and higher education were associated with increased delays, possibly reflecting private healthcare choices. Birth order effects were modest, with second-born children in non-EAG states showing higher odds. Gender differences were negligible. Overall, social determinants, religion, caste, wealth, education, and residence, shaped vaccination timeliness differently across EAG and non-EAG regions.

Vaccination delays in India show marked regional variation, largely driven by differences in healthcare infrastructure, accessibility, awareness, and socio-economic conditions. EAG states, with weaker health systems, report higher delays, particularly among disadvantaged groups such as the poorest households, rural residents, and children of mothers with little or no education. In contrast, non-EAG states generally demonstrate lower delays, though disparities persist across social and economic groups.

Socioeconomic and demographic factors strongly shape vaccination timeliness. Children from the poorest wealth quintile and mothers with no education are at the greatest risk of delay, while higher maternal education and wealth reduce delays. Religion and caste also play important roles: minorities and lower-caste groups face higher risks, particularly in EAG states, underscoring persistent inequities in access to health services. Other determinants include birth order and place of residence. Later-born children are more likely to experience delays, reflecting resource constraints and divided parental attention. Rural children also face more delays due to limited healthcare access. Gender differences are minor, with broadly similar trends for boys and girls.

Overall, BCG delays are most affected by religion, caste, wealth, and birth order, while measles delays follow similar patterns. Addressing these disparities requires strengthening rural healthcare, expanding maternal education, and targeted awareness campaigns for marginalized communities.

V. DISCUSSION

This study examined delays in childhood vaccination in India, focusing on BCG, measles, and DPT vaccines, and highlighted substantial regional and socioeconomic inequalities in vaccine delay.

The findings underscore that although immunization coverage has improved nationally but timely administration of vaccines remains a crucial public health challenge, particularly in the Empowered Action Group (EAG) states.

Consistent with previous studies, vaccination delays were more prevalent in EAG states than in non-EAG states across all vaccines examined [1,8,9]. This regional disparity reflects long-standing differences in health system capacity, infrastructure, and socioeconomic development between these regions [15]. EAG states are characterized by higher poverty levels, lower maternal education, and weaker primary healthcare delivery, all of which contribute to delayed access to immunization services [23].

Religion and caste-based differentials in vaccination delay were evident, with Muslim children and children from Scheduled Caste and Scheduled Tribe households experiencing higher delays, particularly in EAG states. These findings align with earlier NFHS-based and district-level analyses that document persistent social inequities in child health service utilization in India [24,16,18]. Such disparities may arise from a combination of demand-side factors, including lower health awareness, cultural barriers, and mistrust, as well as supply-side constraints such as inadequate outreach in socially marginalized communities [25].

Wealth gradients in vaccination delay were pronounced, especially for BCG and measles vaccines. Children from poorer households were consistently more likely to experience delayed vaccination, while those from richer households had lower delays, although delays were not entirely eliminated even among the wealthiest groups. This suggests that financial disadvantage exacerbates barriers to timely vaccination but does not fully explain delays, pointing to systemic issues within service delivery [26, 27]. Similar patterns have been reported in other low- and middle-income countries, where socioeconomic inequality strongly influences vaccination delay despite nominally free vaccination services [3].

Maternal education emerged as a strong protective factor against delayed vaccination, particularly in non-EAG states. Children of mothers with higher education levels were significantly less likely to experience delays, consistent with evidence that educated mothers are more likely to understand immunization schedules, recognize the importance of timely vaccination, and navigate health services effectively [28-30]. In EAG states, although higher maternal education reduced delays, substantial delays persisted, suggesting that improvements in demand-side factors alone may be insufficient without parallel strengthening of health systems.



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Higher birth order was associated with increased vaccination delay in both regions, supporting the “resource dilution” hypothesis, whereby parental time, attention, and resources are spread more thinly among larger families [31]. This finding has been consistently observed in studies from India and other settings and highlights the need for targeted follow-up of higher-order births through home-based records and reminder systems [32].

Rural children experienced greater delays than urban children, particularly for BCG vaccination. Geographic barriers, limited transportation, and irregular outreach sessions in rural areas likely contribute to this disadvantage [33]. However, the relatively small rural–urban differences observed for measles and DPT vaccines suggest that once children are engaged with the health system, later vaccinations may be delivered more uniformly, albeit still with delays.

Notably, delays in DPT vaccination were extremely high across all sociodemographic groups, with limited variation by wealth, education, or gender. This pattern likely reflects systemic scheduling and service-delivery challenges rather than individual-level socioeconomic factors. Given that DPT and polio vaccines are administered on the same schedule and showed nearly identical delay patterns, focusing on DPT delay provides a robust indicator of delays in multi-dose infant immunization [34].

Importantly, gender differences in vaccination delay were minimal, indicating that overt gender bias in vaccination timing may be less prominent than in earlier decades. This finding aligns with recent national-level studies suggesting a narrowing of gender gaps in immunization coverage and utilization in India [14].

Overall, the findings emphasize that measuring vaccination coverage alone is insufficient to assess immunization program performance. Delayed vaccination prolongs children’s vulnerability to preventable diseases and undermines the population-level benefits of immunization. Addressing vaccination delay requires integrated strategies that simultaneously target demand-side barriers such as caregiver awareness and vaccine confidence and supply-side constraints, including service availability, outreach planning, and health worker capacity. Strengthening monitoring systems to routinely track timeliness, particularly in high-burden EAG states, will be essential for achieving equitable and effective immunization in line with Immunization Agenda 2030.

VI. LIMITATIONS

As NFHS-5 is cross-sectional, causal inferences between predictors and delayed vaccination cannot be established. Information on vaccination dates partly relies on parental recall or vaccination cards, which may introduce recall or reporting bias and the study defines delay based on the national immunization schedule but does not account for the severity or length of delay. Certain factors such as health system access, service quality, and vaccine stock-outs were not available in the dataset and could influence delays. Although nationally representative, variations in local health infrastructure and cultural practices may limit generalizability to specific sub-populations.

VII. POLICY AND PRACTICAL IMPLICATIONS

The findings highlight the need for policy interventions not only to improve overall coverage but also to ensure vaccines are administered on time, thereby maximizing protection against vaccine-preventable diseases. Targeting high-risk groups – Delays were more common across certain socio-demographic and maternal characteristics, suggesting that vaccination campaigns should prioritize disadvantaged populations such as rural households, lower wealth quintiles, and mothers with lower education levels. Since delays are more pronounced in EAG states, targeted investment in health infrastructure, workforce capacity, and monitoring mechanisms is essential to reduce regional disparities. Practical approaches such as mobile health units, improved reminder systems (SMS alerts, ASHA follow-ups), and community awareness programs can help address parental ignorance and logistic barriers. Integration with maternal health programs – Linking immunization services with antenatal and postnatal care visits can improve timeliness by leveraging existing touchpoints between mothers and the health system. Policies should emphasize not only vaccination coverage but also timeliness indicators in routine health information systems to identify delays early and implement corrective action.

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