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Vaccines on time: Exploring determinants of delaying child vaccination in states of India

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ABSTRACT

Aim: Timely vaccination is essential to achieve full potential of the vaccination especially in child population. Despite of success in increasing the coverage in India's universal immunization programme (UIP), timely vaccination remains a challenge. This study aims to understand the key socioeconomic correlates of vaccination delay and guide by charting the future course of action.

Subject & methods: This study was a part of the review conducted in four states namely Madhya Pradesh, Rajasthan, Assam and Haryana to understand the equity issues in immunization. It was a cross-sectional study where 293 mothers of children aged 12–35 months were interviewed using semi-structured questionnaire. Association of delay in immunization and co-variates were examined through multilevel Poisson regression framework.

Results: Timely vaccination was poor for most of the antigens except Measles. Only 52.6% of children had BCG on time and very few for Pentavalent doses as per the scheduled time (Penta-1: 3.4%, Penta-2: 1.4% and Penta-3: none). Whereas, measles showed better coverage (75%) for timely vaccination as compared to other basic antigens. About 72.7% received their basic vaccination in first year of life. Religion and mother's education were found to be associated with delay in all vaccination as per the schedule (at Birth, 6 weeks, 10 weeks, 14 weeks and 9–12 month).

Conclusion: Timeliness of vaccination definitely requires attention to avoid increased risk of infection among children and avoid epidemics and outbreaks. There is a need to increase attention towards urban areas and improve the timeliness of vaccination and utilise the complete potential of the Universal Immunisation Programme (UIP).

1. Background

Immunization is one of the most cost-effective public health interventions to reduce morbidity and mortality associated with Vaccine Preventable Diseases (VPDs).[1] Worldwide immunization have resulted in dramatic declines and regional elimination of many serious childhood infectious diseases.[2] The WHO estimates that globally, 2–3 million deaths could be prevented through immunization.[3] Nonetheless, the WHO also estimates that vaccine-preventable deaths are still responsible for 1.5 million deaths each year.[4] India's immunization program dates back to 1978 when the Expanded Program of Immunization (EPI) was launched by the government of India.[5] India's Universal Immunization Programme (UIP) is the largest in the world, catering to an annual cohort of approximately 26 million infants and 30 million pregnant women through around 12 million sessions[6-]. Immunization landscape in the country is dynamic and rapidly evolving to enhance the provision of quality services to deliver them. The pathway to achieve national immunization goal has been cemented over the past decade with promising achievements, noteworthy being the expansion of the bouquet of immunization services with the introduction of new vaccines, increased budgetary allocation, greater focus on immunization research, innovations and technological advancements, with all key stakeholders

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having a role to play. In addition, fundamental policy changes and innovations such as alternate vaccine delivery, name-based tracking, Open Vial Policy, Electronic Vaccine Intelligence Network and Mission Indradhanush (MI), have been introduced to further strengthen and augment immunization service delivery.[7] The country is performing in alignment with the global goals in controlling and eliminating VPDs, but the progress is very slow.[8] The immunization program in India still suffers with large inequities across various socio-economic strata. As per the latest round of National Family Health Survey-2019-21 (NFHS 5), only 76.4% of the children are fully immunized in India.[9] The data also shows the state level inequality exits in FIC between states of India ranging from 89.2% in Tamil Nadu to 57.9% in Nagaland. Even with the implementation of the Mission Indradhanush (MI) by the Ministry of Health in 2014, to target underserved, vulnerable, resistant, and inaccessible populations, the program only contributed to an increase of 6.7% in full immunization coverage (7.9% in rural areas and 3.1% in urban areas) after the first two phases[7].

The reasons associated with under-vaccination are the ones related to immunization systems, family characteristics, parental attitudes and knowledge, and to limitations in immunization-related communication and information.[10] Previous studies have highlighted on individual predictive factors for vaccination including gender, age, and birth order, and other household factors such as family size, number of children below age three years, household wealth, caste, and maternal education.[11–13] The immunization uptake varies among regions, states, and different groups in the country.[12,14] In India, though full immunization coverage increased over a span of 10 years (i.e. from 2005–06 and 2015–16) but in all states immunization coverage was lowest in children from poorer households and improved with increasing socioeconomic status.[15] Despite increase in immunization coverage over a span of 10 years (i.e. from 2005–06 and 2015–16), economic inequality in terms of coverage still exists, with the full immunization coverage being lowest among children belonging to poorer household. In all states, immunization coverage is lowest among children belonging to poorer households.

Vaccination coverage is monitored as part of Sustainable development Goal 3, which ensure healthy lives and promote well-being for all population with the aim of ending preventable deaths of new born and children under 5 years of age by 2030. At the same time, SDG 10 aims to reduce inequalities within and among countries.[16] As a signatory of Sustainable Development Goal (SDG), India, like other countries, is pledged to secure healthy lives and promote well-being for all, at all ages.[17] However in India, despite the implementation of the UIP programme for more than 30 years, immunization coverage among children aged 12–23 months in the country has increased at a slow pace of almost 1% each year (from 35% in 1992-93 to 62% in 2015-16).[9] Although various efforts and interventions have been made by the government, yet the progress in achieving full immunization coverage has been slow.

Apart from coverage, timely vaccination is a crucial indicator to evaluate the efficiency of the immunization programme. Though the country has been successful in increasing the coverage for the largest cohort of children in world, yet timeliness of vaccination remains a challenge. In India, the immunization schedule of the government-run Universal Immunization Programme is recommended by the National Technical Advisory Group on Immunization (NTAGI)[18] keeping the physiological vulnerability and age specific susceptibility to the specific pathogens.[19] Timely vaccination is essential to achieve full potential of the vaccination especially in early ages.[20] Children receiving delayed vaccinations remain susceptible to vaccine preventable diseases, compromising their own health and also the herd immunity.[21] In a study it was found that children in low and middle income countries, such as India, encounters significant immunization delay.[10] A study conducted in 45 countries found that the timeliness of children's vaccination varies widely between and particularly within countries, and published yearly estimates of national coverage do not capture these variations.[22]

Though, vaccine delay has been a long-standing issue, there are only few studies conducted to estimate and understand the demand and supply-side dynamics of delay in basic vaccination. Using the District Level Health Survey 3 (DLHS 3) survey data, it was found that only 30% of vaccinated infants received the measles vaccine at the recommended age of 9 months and only 31% of infants received DPT-3 vaccine at the recommended age of 14 weeks.[23] In India, according to the latest round of National Family Health Survey (2015–16), the vaccination delay among 10–23 month children was estimated to be 23.1%, 29.3% and 34.8% for BCG, DPT-1st dose and Measles respectively.[24] A study on immunization among low birth weight (LBW) infants indicated that proportion of infants with delayed vaccination for DPT1 and DPT3 were 52% and 81% respectively.[25] The factors associated with the timely immunization among children included quintiles, Muslim religion, age of the mother, birthweight, maternal education.[24–26] A study on the demand-side factors affecting the timely vaccination indicated proper knowledge of vaccination particularly among the male members and father's education as important predictors of timely vaccination.[27]

The UIP has gone through tremendous change in the last five years such as introduction of new vaccines and extra doses. There have been intensive immunization campaigns as *Mission Indradhanush*/Intensified *Mission Indradhanush,* conducted in multiple rounds and community targeted communication interventions, which has brought a paradigm shift towards achieving goal of 90% full immunization coverage and also assured that children should get their vaccine on time. Nevertheless, there is a dearth of studies to understand the timeliness of vaccination and its associated factors post the introduction of interventions. Vaccination delay has serious health risks involved, for instance a measles outbreak in a particular locality can affect almost all the children who have a low immunity, and thus it is essential to have timely vaccination. Moreover literature shows that if children are not administered vaccinations according to the recommended schedule, they not only fail to receive timely protection from preventable diseases at a time when they are most vulnerable, but also increase their risk of never fully completing the vaccination course.[19] Given the health risks associated with vaccination delay and the importance of timely vaccination this study aims to understand the socioeconomic correlates of vaccination delay and chart the future course of action to gain the achievement in absence of evidences from large surveys.

2. Methods and materials

2.1. Data source

The present study is part of the review conducted in four states namely Madhya Pradesh, Rajasthan, Assam and Haryana to socio-economic factors effecting immunization. To accomplish the objective, one district was randomly selected from each state having poor immunization coverage as per NFHS-4 (2015–16) data. In total it covered 293 households having children of age group 12–35 months. It was a cross-sectional study where mothers of children aged 12–35 months were interviewed using semi-structured questionnaire. The survey collected information on the basic socio-demographic details such as age of child and parents, sex, type of residence, family composition, socioeconomic details, parental education and occupation. Other information such as availability of mother and child protection (MCP) card, place of delivery of the child, preferred system for treatment, preferred system for immunization and follow up after immunization were also collected.

2.2. Dependent variable

The dependent variable used in the analysis is the delay in various vaccination. In the survey the immunization status of children was ascertained through dates mentioned for vaccines in MCP card. Immunization status was categorized as timely, delayed, partial and no immunization. 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 Pentavalent 1, 10 weeks for Pentavalent 2, 14 weeks for Pentavalent 3 and 9–12 months for Measles.

2.3. Explanatory variable

In order to assess the factors that affected timeliness of vaccination among children a number of socio-demographic variables were considered. These include age of child and parents, sex, type of residence, family composition, socioeconomic details, parental education and occupation. Other information such as availability of mother and child protection (MCP) card, place of delivery of the child, preferred system for treatment, preferred system for immunization and follow up after immunization were also included as explanatory variables in the analysis.

2.4. Ethical consideration

The study was based on UIP review data from five states which was done by JSI India in collaboration with ministry of health and family welfare (MOHFW) in India with all ethical standards being complied for review. The Institutional ethics review board of JSI has been approved the study.

2.5. Statistical analysis

Association of immunization status and co-variates were examined through multivariate analysis. Socioeconomic status was defined through household wealth index which was generated using principal component analysis (PCA) scores in STATA 13.0. This score was then divided into three parts defining it as poor, middle and rich.

We modeled each of the outcome variables–delay for each antigen (in weeks) separately using multilevel Poisson regression models. Multilevel modelling is an approach that is used to handle clustered or grouped data for valid estimates and standard errors. Here in our study, a two-level model which allowed to include residuals at the children as well as district level was used. Thus, the residual variance was partitioned into between-district component (variance of the district-level residuals) and within-district component (variance of the child-level residuals). The district residuals represented the unobserved district characteristics which would have affected the children immunization outcomes.

The general equation for multilevel Poisson regression is as follows

Level 1 Poisson Models: $\log\mu_{ij} = \beta_{0j} + \beta_1 X_{1.1j} + \beta_2 X_{2.2j}$

Level 2 Poisson Models: $\beta_{0j} = \gamma_{00} + \gamma_{0i}\, X_{2.j} + u_{0j}$

Poisson Mixed Models: $\log\mu_{ij} = \gamma_{00} + \gamma_{0i}\, X_{2.j} + \beta_1 X_{1.1j} + \beta_{2j}\, X_{2.2j} + u_{0j}$

With i = district 1,2, 3, …,nj and j = children in the district Statistical package of R and STATA were used for data analysis. State was used as first level to account for state level variation, and other factors in the second level of the model. Modeling was done using R for the multi-level models. Family of model used was Poisson due to nature of outcome variable which was delay in weeks.

3. Results

In the sample of children, 63.1% were from rural areas. Hindus (92.1%) were the dominant religious group with 48.1% scheduled Tribes and 43.7% general caste population. Most of families were found to have more than six members (44.7%) followed by two to four members (28%). Most of the mothers aged below 29 years (83.3%), whereas highest proportion of fathers were of 30 years and above (43.6%). More than half of mothers (54.9%) were educated above class eighth of formal education, and a large proportion (68.3%) of mothers had no formal employment. Proportion of male and female children were almost equal in the sample (female:52.5% and male: 47.5%). We found that 43% of children were of 1st birth order, 38.1% were of 2nd order and rest were of 3rd or higher order. Around 71% of children were delivered in government institutions and almost equal proportion of parents preferred government health services over others (71.7%). When enquired about preferred immunization site, 53.1% said government outreach sessions, 38.9% preferred government health facilities and 8% preferred private facilities. About 80% of the households were followed-up by the front-line health workers after vaccinations (Table 1).

Timely vaccination was poor for most of the antigens except Measles (Fig. 1). Only 52.6% of children had BCG on the day or on the next day of birth. Very few children received Pentavalent doses as per the scheduled time (Penta-1: 3.4%, Penta-2: 1.4% and Penta-3: none). Measles showed better coverage for timely vaccination as compared to other basic antigens (75%). This might be due to longer time interval (9 months–12 months) for administering vaccines as per the recommended schedule (Table 2). About 72.7% of children received all basic vaccination in their first year of their age and another 16.7% received by second year of their age.

Adjusted model shows that children in urban areas were 1.67, 1.13 and 2.18 time more prone to delay BCG, Pentavalent 3 and Measles, respectively, than in rural areas. Religion was significantly associated with delay in all the antigens. Muslims were more likely to delay all vaccines as compared to Hindus [BCG: 4.14 (95% CI: 2.94, 5.81),

Table 1
Distribution of sample in the review area.

Predictors	Sub-categories	n (%)
Type of residential area	Rural	185 (63.1)
	Urban	108 (36.9)
Socio-economic status	Poor	98 (33.5)
	Middle	98 (33.4)
	Rich	97 (33.1)
Religion	Hindu	269 (92.1)
	Muslim	23 (7.9)
Caste	Scheduled Tribe	141 (48.1)
	Scheduled Caste	24 (8.2)
	Others	128 (43.7)
Number of Family members	Two to four members	82 (28.0)
	Five to six members	80 (27.3)
	More than six members	131 (44.7)
Age of mother	24 years or less	121 (41.3)
	25–29 years	123 (42.0)
	30 years or more	49 (16.7)
Age of father	24 years or less	47 (16.2)
	25–29 years	117 (40.2)
	30 years or more	127 (43.6)
Education of mother	No schooling	70 (23.9)
	Up to class 8	62 (21.2)
	More than class 8	161 (54.9)
Occupation of mother	Not working	200 (68.3)
	Agricultural/live stocking	41 (14.0)
	Others	52 (17.7)
Sex of the child	Female	154 (52.5)
	Male	139 (47.5)
Birth order of the child	1st Order	125 (43.0)
	2nd Order	111 (38.1)
	3rd Order and above	55 (18.9)
Place of delivery of the child	Home delivery	15 (5.1)
	Private institution	70 (23.9)
	Government institution	208 (71.0)
Preferred health services	Government health services	210 (71.7)
	Others	83 (28.3)
Preferred place for immunization services	Outreach AWC	146 (53.1)
	Government Health Facilities	107 (38.9)
	Non-government	22 (8.0)
Households followed up by FLWs after vaccination	Yes	213 (79.5)
	No	55 (20.5)

Note: In few categories' numbers may not add up to 293 due to missing or were not applicable to all.

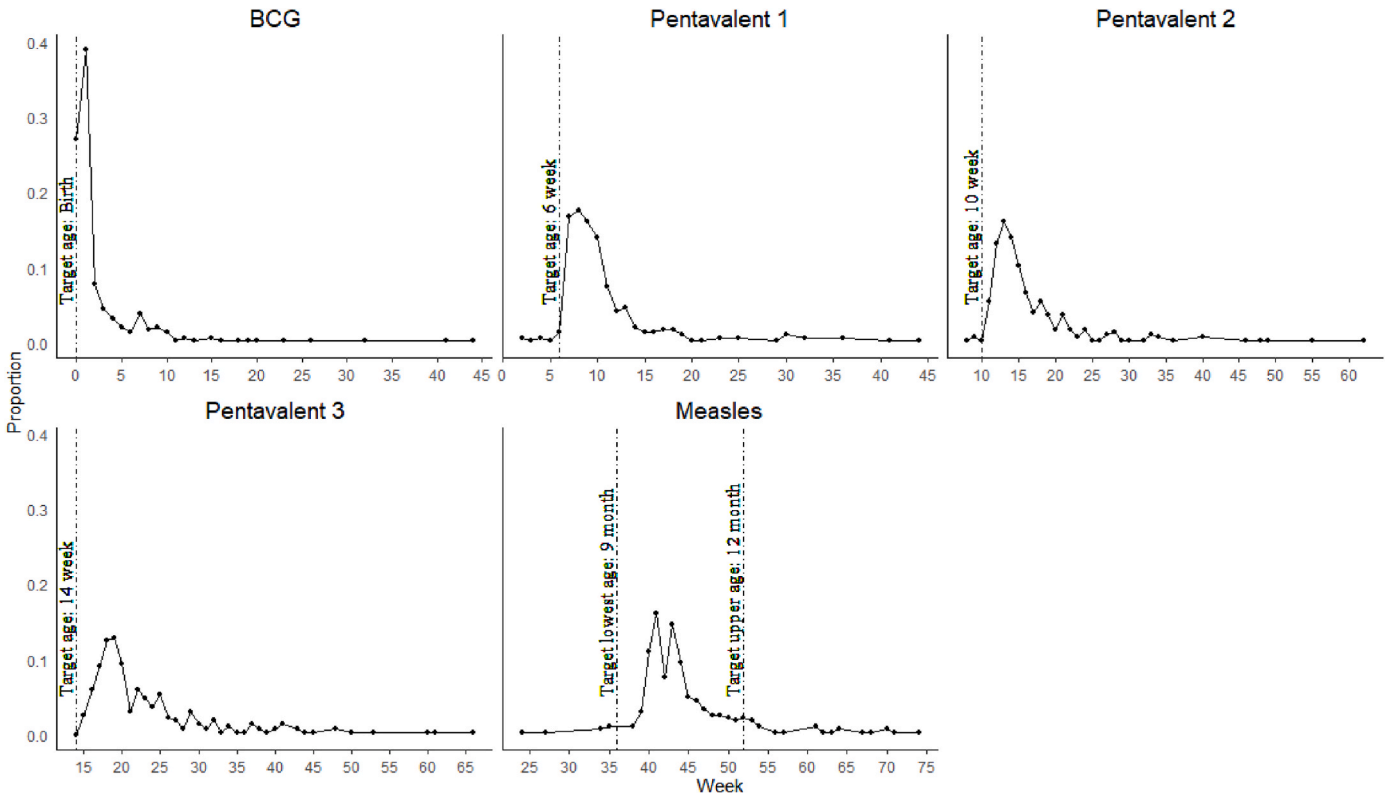

Fig. 1. Distribution curve of antigen wise coverage as per age of child.

Table 2
Antigen wise coverage at recommended age and different age intervals.

	BCG	Pentavalent 1	Pentavalent 2	Pentavalent 3	Measles 1
Target age	Birth	6 weeks	10 weeks	14 weeks	9–12 months
Coverage at					
Birth	52.6				
6 weeks	81.6	3.4			
10 weeks	90.4	64.8	1.4		
14 weeks	91.8	82.6	46.8	0.0	
5 months	93.9	90.1	76.5	47.4	
6 months	94.2	91.1	84	63.5	0.3
9 months	94.9	94.5	90.1	81.2	2.4
12 months	95.6	95.2	91.5	87.7	72.7
18 months	95.6	95.2	92.5	89.4	88.4
24 months	95.6	95.2	92.5	90.1	89.4
Unvaccinated	**4.1**	**4.8**	**7.2**	**9.6**	**10.6**

Pentavalent-1: 1.80 (1.39, 2.33), Pentavalent-2: 1.36 (1.06, 1.74), Pentavalent-3: 1.28 (1.03, 1.60), Measles: 6.60 (2.91, 14.99)]. Caste was significantly associated with delay in BCG and Measles only. Schedule Tribe [2.35 (1.77, 3.12)] and Schedule Caste [1.77 (1.27, 2.47)] children had higher chance of delaying BCG vaccine compared to the other children. Risk of delay as per socio-economic index showed that children from middle class and rich families had higher chances of delay in BCG and measles than poor children – BCG [Middle: 1.95 (1.46, 2.60), Rich: 3.13 (2.28, 4.29)] and Measles [Middle: 2.24 (1.29, 3.89), Rich: 4.16 (2.06, 8.42)]. Larger family size and older aged mothers (30 & above years) were significantly associated with delay in Pentavalent-1, Pentavalent-3 and BCG, respectively. Higher education of mother had significantly reduced the chances of delay in all antigens (Table 3) (see Table 4).

Children of working mothers had higher risk of delaying Pentavalent 1 (Agriculture or livestock: 1.53 (1.22, 1.91), other work: 1.22 (1.02, 1.47)) and for Pentavalent 2 (Agriculture or livestock: 1.28 (1.07, 1.54), other work: 1.28 (1.09, 1.49)) than children of home makers. Male children had lower chances of delay in immunization of Pentavalent 2 and 3 but higher in Measles vaccine. Institutional delivery reduces the chances of delay in BCG [government facility- 0.74 (0.60, 0.92); private facility-0.26 (0.21, 0.33)]. Families preferring government facilities for treatment had lower chance of delay in Pentavalent-1 (0.69 (0.59, 0.81)), Pentavalent-3 (0.86 (0.77, 0.97)) and Measles (0.61 (0.38, 0.99)) but had higher chances of delay in BCG (1.99 (1.59, 2.48)) administration as compared to the families preferring private facilities. Similarly, families preferring outreach facility for availing immunization had higher chance of delay in BCG (2.77 (2.17, 3.54)) than those who preferred government health facility. Further, children having no follow-up after vaccination had higher chance of delay in BCG (2.65 (2.17, 3.23)) and Pentavalent-3 (1.17 (1.04, 1.31)) vaccination as compared to the children of families reporting follow-up by FLW after vaccination (Table 3).

Table 3
Adjusted multi-level model predicting factors associated with delay in vaccination.

	BCG		Pentavalent 1		Pentavalent 2		Pentavalent 3		Measles	
	Risk ratio	95% CI	Risk ratio	95% CI	Risk ratio	95% CI	Risk ratio	95% CI	Risk ratio	95% CI
Residential area	****						****		****	
Rural	Ref		Ref		ref		ref		ref	
Urban	1.67	1.26, 2.22	0.90	0.76, 1.07	0.93	0.80, 1.07	1.13	1.01, 1.28	2.18	1.27, 3.74
Religion	****		****		****		****		****	
Hindu	Ref		Ref		ref		ref		ref	
Muslim	4.14	2.94, 5.81	1.80	1.39, 2.33	1.36	1.06, 1.74	1.28	1.03, 1.60	6.60	2.91, 14.99
Caste	****									
Others	Ref		Ref		ref		ref		ref	
Scheduled Caste	1.77	1.27, 2.47	1.14	0.88, 1.47	0.88	0.71, 1.09	0.85	0.71, 1.01	7.70	3.79, 15.62
Scheduled Tribe	2.35	1.77, 3.12	0.81	0.66, 1.01	0.84	0.70, 1.01	0.90	0.77, 1.04	0.70	0.37, 1.34
Socio-economic index	****								****	
Poor	Ref		Ref		ref		ref		ref	
Middle	1.95	1.46, 2.60	0.92	0.77, 1.10	1.26	1.08, 1.46	1.22	1.08, 1.38	2.24	1.29, 3.89
Rich	3.13	2.28, 4.29	0.96	0.76, 1.21	1.04	0.85, 1.28	0.93	0.78, 1.10	4.16	2.06, 8.42
Number of members					****					
Two to four members	Ref		Ref		ref		ref		ref	
Five to six members	0.94	0.70, 1.25	1.39	1.16, 1.67	1.27	1.08, 1.48	1.19	1.05, 1.35	0.79	0.44, 1.43
More than six members	1.16	0.90, 1.48	1.17	0.99, 1.40	1.24	1.07, 1.43	1.00	0.89, 1.13	0.98	0.59, 1.62
Age of Mother	****									
24 yrs or less	Ref		Ref		ref		ref		ref	
25–29 yrs	1.58	1.25, 1.99	0.93	0.80, 1.08	0.90	0.80, 1.03	0.94	0.84, 1.04	1.70	1.01, 2.88
30 yrs or more	1.95	1.43, 2.65	0.78	0.61, 0.99	0.66	0.53, 0.81	0.80	0.68, 0.95	0.97	0.46, 2.02
Education of Mother	****		****		****		****		****	
No education	Ref		Ref		ref		ref		ref	
8th class or less	0.28	0.20, 0.40	0.56	0.46, 0.68	0.47	0.40, 0.56	0.53	0.46, 0.62	0.20	0.10, 0.40
More than 8th class	0.62	0.47, 0.83	0.52	0.44, 0.63	0.43	0.37, 0.50	0.54	0.47, 0.61	0.41	0.23, 0.72
Occupation of Mother			****		****					
Not working	Ref		Ref		ref		ref		ref	
Agriculture or live stock	1.89	1.32, 2.71	1.53	1.22, 1.91	1.28	1.07, 1.54	1.09	0.93, 1.27	0.37	0.19, 0.74
Other	0.78	0.60, 1.01	1.22	1.02, 1.47	1.28	1.09, 1.49	1.26	1.11, 1.44	1.63	0.95, 2.78
Gender of child					****		****		****	
Female	Ref		Ref		ref		ref		ref	
Male	1.19	0.98, 1.44	1.00	0.87, 1.13	0.80	0.71, 0.89	0.84	0.77, 0.93	1.65	1.10, 2.46
Birth order of child										
1st order	Ref		Ref		ref		ref		ref	
2nd order	1.88	1.51, 2.35	1.19	1.01, 1.39	0.95	0.83, 1.09	0.96	0.86, 1.07	0.96	0.56, 1.63
3rd order or more	0.91	0.64, 1.29	1.06	0.84, 1.33	0.92	0.76, 1.13	0.70	0.59, 0.83	2.91	1.52, 5.56
Delivery place of child	****									
Home delivery	Ref		Ref		ref		ref		ref	
Private hospital	0.26	0.21, 0.33	0.74	0.62, 0.90	0.89	0.75, 1.05	0.86	0.74, 0.99	1.58	0.90, 2.76
Government hospital	0.74	0.60, 0.92	1.16	0.97, 1.39	1.01	0.87, 1.18	1.13	0.99, 1.28	3.88	1.94, 7.75
Preferred system for treatment	****		****				****		****	
Private Health services	Ref		Ref		ref		ref		ref	
Government Health services	1.99	1.59, 2.48	0.69	0.59, 0.81	0.94	0.82, 1.08	0.86	0.77, 0.97	0.61	0.38, 0.99
Preferred service place for immunization of child	****									
Government Health facility	Ref		Ref		ref		ref		ref	
Outreach facility	2.77	2.17, 3.54	0.95	0.81, 1.11	0.88	0.77, 1.01	1.10	0.98, 1.24	1.60	0.97, 2.65
Follow up by health care provider	****						****			
Yes	Ref		Ref		ref		ref		ref	
No	2.65	2.17, 3.23	1.13	0.96, 1.34	0.94	0.81, 1.09	1.17	1.04, 1.31	1.22	0.73, 2.05

**** p-value <0.01.

Table 4
Summary of statistically significantly associated factors.

	BCG	Pentavalent 1	Pentavalent 2	Pentavalent 3	Measles
Residential area	✔			✔	✔
Religion	✔	✔	✔	✔	✔
Caste	✔				
Socio-economic status	✔				✔
Age of Mother	✔				
Education of Mother	✔	✔	✔	✔	✔
Occupation of Mother		✔	✔		
Gender of child			✔	✔	✔
Delivery place of child	✔				
Preferred system for treatment	✔	✔		✔	✔
Preferred care center for immunization of child	✔				
Follow up by health care provider	✔			✔	

4. Discussion

Identifying and understanding the factors related to social determinants on delay in routine immunization programs in India is important to improve both vaccination coverage and timeliness of vaccination. This study provides important information regarding timely immunization coverage, as well as associated factors for delay in vaccination, specifically for children up to 2 years belonging to the four states of India. Results showed that overall coverage of the basic vaccination was satisfactory, but there was substantial delay in administration of vaccines as per the recommended schedules for each antigen.

The findings showed that place of residents, religion, education of mother, age and gender of the child were important socio-demographic factors which influenced delay in vaccination. Apart from the aforementioned factors, delivery place, preferred system of treatment, preferred care center for immunization and follow up of health care provider were important factors which determined the delay in getting BCG vaccine.

The most critical finding was the increasing trend of delay with each vaccine schedule except Measles, which was also observed in previous study.[19] Finding shows that the delay was highest in Pentavalent-3 followed by Pentavalent-2, Pentavalent-1, BCG and Measles. This suggests that there is significant effort required to bring change in achieving timely vaccination for each antigen coverage which will help in managing the dropouts and missed out.

We found that children residing in urban areas had higher chance of delaying BCG, Pentavalent 3 and Measles vaccines, which is a marked shift from previous studies which showed that rural residents had higher risk of delay or non-vaccination.[12,23] This could be due to the reform brought about by the introduction of National Rural Health Mission, which made it possible for the health system to reach the underprivileged population in rural area. At the same time, it can also be due to poor immunization service delivery in urban settings. Since urban population mostly depend on the private facilities for vaccination, this creates a delay in getting vaccinated. Socio-economic categories showed clear gradient of increased risks of delay in BCG and Measles vaccination with improvement in wealth status, which was contrary to previous findings from NFHS 4.[24]

As per the study, being Muslim had higher chance of delaying vaccination as compared to Hindus. The result is in line with numerous studies which had also found Muslims to be at high risk of delay or no vaccination. This underlines further intervention to bring awareness and build confidence among the Muslim community. Similarly, Schedule Tribe and Schedule Castes were also at risk of delay in BCG vaccination, which has been affirmed with other studies.[25,27] This could be due to their settlement pattern and low awareness levels as health system find difficultly in providing services in the remote areas.[28]

Mother's characteristics such as increasing age, education and occupation were found to be associated with vaccination delay. The risk of BCG delay was higher in older age group mothers. Higher chances of delay in Pentavalent 1 and Pentavalent 2 were found in working mothers. Lower risk of delay in all vaccines was found in higher educated groups in compared to those with no formal education. Mother's education has always been a deciding factor for the child health[29] and immunization[25,30–33] as it influences the health seeking behavior of whole family.[34] Males had lower risk of delay in Pentavalent 2 and Pentavalent 3 but had higher risk in Measles vaccine administration.

It is also observed from the data that the child delivered in a government health facility had a substantially lower risk of delaying BCG vaccine as compared to those born in private health facility. This is also in line with previous studies that examined the relation.[23,27,32,33] Additionally, it was found that those who preferred private healthcare for treatment had lower risk of BCG vaccine, however, their probability of delay was higher for other vaccines indicating a poor private immunization system in the country. Similarly, it was found that those relying more on outreach services, tend to delay BCG more than those relying more on health facilities for immunization and it could be due to the most probable reason that in outreach session those children are covered who missed their birth doses and were covered through outreach facilities.

Follow up visits play a crucial role in building the confidence of the beneficiaries in health system and ensure full and timely immunization.[35] We found that not following up the beneficiaries after vaccination was associated with delay in BCG and Pentavalent 3 vaccines.

The study identified the predictors of timely immunization and some of them are somewhat similar to the conventionally known predictors of routine childhood immunization, such as the socio-economic characteristics of the mother. The immunization program needs to consider all these factors. The first and foremost thing is creating awareness about the importance of timely vaccination among not only the mothers but also the fathers and family member at large. The immunization program should focus on the Muslim community and children of the SC and ST caste groups as both coverage and timeliness are a major concern among those children. There is also the need to create a need of urgency among both the service providers (public and private sector) as well as in the parents in order to address the issue of timeliness in child immunization. Not only is routine monitoring of coverage, but UIP should also track the timeliness of child immunization. There should be a constant monitoring of follow up by the health care providers to improve both coverage and timeliness of immunization.

5. Limitation

This study was conducted with a small sample in select four districts of four states. Therefore, the results should be generalized with caution. Similarly, few sub-categories had small samples, so results pertaining to those groups should be considered carefully. The study did not capture the longitudinal perspective and India level data to know the geographical variation in delay of child immunization.

6. Conclusion

This study underlines the current problem of delay in vaccination. Delay in vaccination increases with next schedule and become maximum for Pentavalent 3. It was found that urban area, religion, mother's education were the most influential factors effecting the delay in administration of all the vaccines. There has been significant gain in coverage but timeliness of vaccines is very poor. Also, this creates greater chances of epidemics and outbreaks in the neighborhood. There is need to revamp the efforts focusing on urban areas, Muslim population and increase in mother's education to improve the timeliness of vaccination and achieve the goal of 90% coverage.

Authors contribution

Conceived and designed the research paper: PD, analysed the data: DP PS, GKS, Wrote the manuscript: AA, AR and AK, AR, AKS; Refined the manuscript.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Ethical treatment of experimental subjects (animal and human)

The study was based on UIP review data from five states which was done by JSI India in collaboration with ministry of health and family welfare (MOHFW) in India with all ethical standards being complied for review. The Institutional ethics review board of JSI has been approved the study.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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