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Original Research Article

Tracking immunization milestones: a community-based survey of child vaccination compliance from birth to one year age in India

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ABSTRACT

Background: Immunization is a crucial public health intervention that significantly reduces childhood morbidity and mortality. In India, despite the efforts of programs like the universal immunization program (UIP), there remain significant challenges in ensuring timely vaccination. This study investigates the compliance with immunization schedules among children in a rural area of Varanasi, India, from birth to one year of age.
Methods: A prospective cohort study was conducted from November 2022 to February 2024, involving 150 newborns. The participants included infants delivered via both caesarean section (CS) and vaginal delivery. Monthly delivery lists from the community health centre facilitated the identification and random selection of eligible newborns. The study entailed a baseline visit followed by four quarterly follow-ups over one year.
Results: The study revealed significant delays in vaccination timing. Hepatitis B had the highest on-time rate at 99.3%, while rotavirus-1 had the highest delay at 35.5%. Other notable delays included BCG (15.8%) and oral polio vaccine (OPV) birth (25.3%). The on-time rates for subsequent doses of OPV and pentavalent vaccines ranged from 65.9% to 77.7%, with delays observed in about a quarter of the vaccinations. Socio-demographic factors indicated a predominance of joint families (85.3%), with most parents having completed high school or higher education.
Conclusions: The findings highlight the need for enhanced strategies to improve adherence to vaccination schedules in rural areas. Significant delays in immunization, particularly for rota-1 and OPV doses, underscore the necessity for targeted interventions.

Keywords: Immunization coverage, Vaccination adherence, Rural health, Childhood vaccination

INTRODUCTION

In the realm of public health, immunization stands as one of the most potent shields against infectious diseases, safeguarding communities from the threat of debilitating illnesses. The first year of a child's life marks a critical period for establishing immunity against a range of potentially harmful pathogens. National immunization schedules (NIS) meticulously outline the recommended vaccines and their administration timelines, aiming to provide optimal protection to infants from birth through their formative months. However, the efficacy of these schedules relies heavily on the adherence of caregivers and healthcare systems to ensure timely vaccinations.

According to the world health organization (WHO), vaccines prevent up to three million deaths annually worldwide, making them one of the most successful and cost-effective public health interventions available.[1] The number of zero-dose children, those missing out on any vaccination, improved from 18.1 million in 2021 to 14.3 million in 2022, nearly reaching the pre-pandemic 2019 level of 12.9 million. The coverage of the third dose of the vaccine protecting against diphtheria, tetanus, and

pertussis (DTP3) recovered from 81% in 2021 to 84% in 2022. Similarly, the proportion of children receiving the first dose of the measles vaccine increased from 81% in 2021 to 83% in 2022, though it remains below the 2019 level of 86%. Global coverage for the first dose of the HPV vaccine in girls rose from 16% in 2021 to 21% in 2022. However, the coverage of the yellow fever vaccine in at-risk countries is 48%, significantly below the recommended 80%. In the United States, the centre for disease control and prevention (CDC) recommends a series of vaccinations for children from birth to six years old, with specific schedules tailored to ensure maximum protection against diseases such as measles, mumps, rubella, and polio.[2]

The WHO launched the expanded program on immunization (EPI) globally in 1974, aiming to prevent six childhood vaccine-preventable diseases by the year 2000. The government of India endorsed this initiative in 1978. Subsequently, on November 19, 1985, India introduced the UIP with the goal of covering at least 85% of all infants by 1990. Further, a national socio-demographic goal was setup in national population policy (NPP 2000) to achieve universal immunization against all vaccine preventable diseases by year 2010.[4] In 2019, India recorded the highest number of diphtheria and tetanus cases worldwide and ranked among the top 10 countries for pertussis and measles cases. Between 2000 and 2020, the annual incidence rates for these diseases in children under five in India averaged 32.8 per 100,000 for measles, 3.5 for diphtheria, 31.1 for pertussis, and 3.3 for tetanus. In 2010, measles accounted for about 3% of all under-five deaths in India, while tetanus caused approximately 20 deaths per million live births during the same period. This contrasts sharply with other low- and middle-income countries that have substantially lower under-five mortality from vaccine-preventable diseases (VPDs) compared to India. Although the overall cases for these VPDs have declined steadily over the past decade, India's poor global ranking raises questions about the low vaccine effectiveness despite nearly 80% immunization coverage following the initiation of the UIP in 2012.[5]

Immunization services are provided free of cost in India through the public healthcare delivery system and include both immunization and outreach session sites and birth doses at public healthcare facilities.[6] The NIS for the first 12 months includes BCG, hepatitis B, and OPV-0 at birth; three doses each of OPV, pentavalent, and rotavirus vaccines at 6, 10, and 14 weeks; inactivated poliovirus vaccine (IPV) at 6 and 14 weeks; and the first doses of measles/MR, Japanese encephalitis-1 (in endemic areas), and vitamin A at 9 to 12 months.[7]

Recent data underscores these challenges: as of 2023, coverage rates for essential vaccines such as hepatitis B (84%), rotavirus (70%), (BCG) (91%), and pentavalent vaccine (86%) varies significantly across different states in India. Dropout rates, a critical metric indicating the percentage of children who do not complete the full vaccination schedule, remain alarmingly high in some regions, with up to 25% dropout observed between doses.[7] It was reported in earlier studies that complete age-appropriate vaccination was less than 50% in India, for BCG and OPV age-appropriate vaccination was less than 80% and for DPT and Measles age-appropriate vaccination was less than 60%.[8]

In this article, we delve into the intricate landscape of childhood immunization compliance within a community setting, focusing on the pivotal milestones from birth to one year of age. Through a comprehensive survey conducted on 150 children, we aim to illuminate the journey of vaccination adherence, shedding light on the successes (reducing dropout rate), and potential areas for improvement within the healthcare infrastructure. By tracking the immunization trajectories of these infants, we endeavour to unravel the intricacies of community-level vaccination practices and their implications for public health outcomes.

METHODS

This prospective cohort study was conducted by the department of community medicine, institute of medical sciences, Banaras Hindu university, Varanasi, over a period, from November 2022 to February 2024, in the rural area of Varanasi, India, focusing on newborns delivered via CS or vaginal delivery. After obtaining institutional ethical clearance, data collection commenced with newborns whose mothers were permanent residents of the study area and whose parents had provided written consent. Exclusion criteria encompassed stillbirths, multiple pregnancies, newborns delivered to mothers temporarily residing elsewhere, and those without parental consent. Data collection involved a pre-designed and validated semi-structured questionnaire, supplemented by measurements of weight, height, head circumference, chest circumference, and mid-arm circumference. Identification of newborns was facilitated through monthly lists of deliveries obtained from the community health centre of Cholapur block, Varanasi, with randomly selecting eligible children. The study included a one-year follow-up period comprising a baseline visit and four subsequent visits every three months, totalling five visits for each child.

Sample size calculation

$$n_1 = \frac{\left(z_{1-\frac{\alpha}{2}}\sqrt{(k+1)\bar{p}(1-\bar{p})} + z_{1-\beta}\sqrt{p_0(1-p_0)+kp_1(1-p_1)} \right)^2}{k(p_1-p_0)^2}$$

Where,

$$n_0 = kn_1$$

$$\bar{p} = \frac{(kp_0 + p_1)}{(k+1)}$$

To determine the sample size for the present study the parameters considered include the prevalence of ARI in children born by vaginal delivery (p_0=0.25) and an estimated relative risk (RR=2.78) (Tefera et al), suggesting a prevalence of p1=0.695 in children born by CS.[21] The ratio of unexposed to exposed groups (k=4) reflects proportion of births by CS in rural India (17.6%, NFHS-5), adjusted for a 10% non-response rate and correction for continuity. Sample size calculations, using CI ($Z_{1-\alpha/2}$=1.96) and power ($Z_{1-\beta}$=1.28), resulted in a total of 150 samples, with a distribution of participants including 30 in CS group and 120 in vaginal delivery group.

RESULTS

The socio-demographic characteristics of the 150 subjects reveal that the mean age of mothers was 25.27±2.81 years, while fathers average 29.01±3.76 years. Education levels vary, with a majority of mothers (52.7%) and fathers (46.7%) having completed high school or intermediate education. Mothers are predominantly housewives (86.7%), whereas fathers are mainly employed in private sector (30.0%) or business (35.3%). Sample is primarily Hindu (84.0%) and largely comprises other backward classes (OBC) at 60.0%, with a followed by scheduled castes (SC) at 22.0%. Most families (85.3%) are joint or 3rd generation, with only 14.7% being nuclear families. This demographic overview indicates a community where traditional family structures and diverse educational and occupational backgrounds are prevalent (Table 1).

The mother and child characteristics data reveals that the mean age at menarche for mothers is 12.97 years, with marriage typically occurring at 21.45 years. Mothers have an average of 1.77 pregnancies, and their mean age at the time of the current birth is 25.27 years. Among the children, 32.0% were born within a year of their previous sibling, 47.3% between one and two years, and 20.7% after more than two years. Nearly half of the mothers (46.0%) were experiencing their first birth, while 54.0% were multiparous. The birth order indicates that 46.0% of children are first-borns, 42.7% are second-born, and 11.3% are third-born or later. Regarding gestation, 10.7% of the births were pre-term, 86.7% were term, and 2.7% were post-term. Modes of delivery show that 20.0% were via CS, with 43.3% of these being elective and 56.7% emergency, while the remaining 80.0% were normal vaginal deliveries. This comprehensive data set highlights the reproductive and childbearing patterns within the studied group, indicating prevalent early marriages, typical pregnancy frequencies, and a predominance of normal term births and vaginal deliveries (Table 2).

The Figure 1 depicts the coverage and dropout rates of immunizations from birth to one year. Hep-B and BCG vaccinations have the highest coverage rates at 99.3%, but this drops to 88.7% for the OPV birth dose. Coverage remains relatively high for OPV-1 at 92.0% but then declines progressively for subsequent doses: 82.7% for OPV-2, 72.0% for OPV-3, and 68.7% for IPV. Coverage peaks again at 91.3% for pentavalent first dose but declines for pent-2 (80.7%) and continues to drop for pent-3 (71.3%), rota-1 (73.3%), rota-2 (67.3%), rota-3 (62.0%), before slightly increasing to 74% for MR and 70.7% for vitamin A. Dropout rates start at 0% for hep-B, OPV birth, and OPV-1, and then increase: 10.6% for BCG, 7.3% for OPV-2, 16.6% for OPV-3, and peak at 27.3% for IPV. Dropout rates decrease to 8.0% for pent-2, then rise again to 18.6% for pent-3, 28.0% for rota-1, 26.0% for rota-2, and peak at 32.0% for rota-3 before declining to 25.3% for MR and 28.6% for vitamin A. This indicates a high initial vaccination coverage with significant dropouts as the schedule progresses, showing the critical points where interventions may be needed to maintain higher coverage rates (Figure 1).

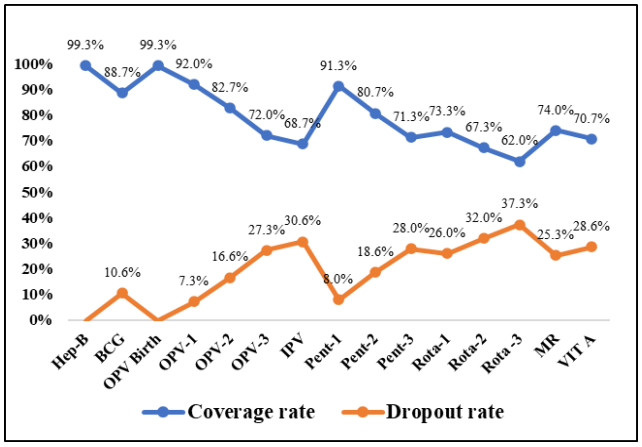

Figure 1: Coverage rate and dropout rate of immunization.

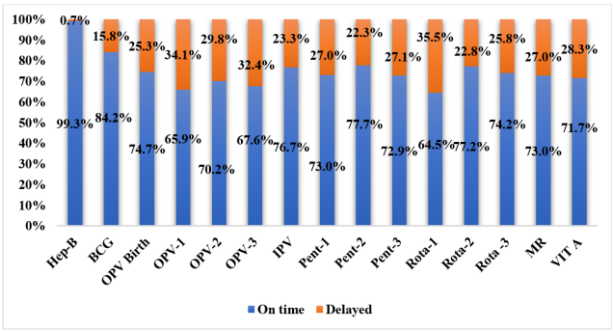

Figure 2: Vaccination timing of children for different vaccines.

The study depicted vaccination timing for 150 children, highlighting both on-time and delayed vaccinations. Hep-B had the highest on-time rate at 99.3%, whereas rota-1 experienced the highest delay at 35.5%. Significant delays were noted for BCG and OPV birth, at 15.8% and 25.3%, respectively. The on-time rates for OPV-1, OPV-2, and OPV-3 were 65.9%, 70.2%, and 67.6%, with corresponding delays of 34.1%, 29.8%, and 32.4%. Pent-1 and pent-2 vaccinations were on time for 73.0% and 77.7% of the children, with delays of 27.0% and 22.3%. pent-3 had a 72.9% on-time rate, with 27.1% delayed. MR and VIT A vaccinations were on time for 74.2% and 71.7%

of the children, with delays of 25.8% and 28.3%. These findings identified the need for improved adherence to vaccination schedules, particularly for Rota-1, which had the most significant delays (Figure 2).

Table 1: Socio-demographic characteristics of study subjects, (n=150).

Variables		N	Percentage (%)
Mother's age (in years)	Mean age: 25.27±2.81		
Mother's education	Illiterate	1	0.7
	Primary and middle	17	11.3
	High school and intermediate	79	52.7
	Graduation and above	53	35.3
Mother's occupation	Government service	5	3.3
	Private	9	6.0
	Business	4	2.7
	Skilled labourer	2	1.3
	Housewife	130	86.7
Father's age (in years)	Mean age: 29.01±3.76		
Father's education	Illiterate	1	0.7
	Primary and middle	19	12.7
	High school and intermediate	70	46.7
	Graduation and above	60	40.0
Father's occupation	Agriculture	5	3.3
	Government service	6	4.0
	Private	45	30.0
	Business	53	35.3
	Unskilled labourer	8	5.3
	Skilled labourer	29	19.3
	Unemployed	4	2.7
Religion	Hindu	126	84.0
	Muslim	24	16.0
Caste	SC	33	22.0
	ST	4	2.7
	OBC	90	60.0
	Others	23	15.3
Type of family	Nuclear	22	14.7
	Joint/3rd generation	128	85.3

Table 2: Mother and child characteristics, (n=150).

Mother's characteristics		Mean±SD	
Age at menarche (in years)		12.97±0.639	
Age at marriage (in years)		21.45±1.46	
Total no. of pregnancies		265,1.77±0.87	
Age at time of current birth (in years)		25.27±2.81	
Child characteristics		**N**	**Percentage (%)**
Birth interval (in years)	<1	26	17.3
	1-2	93	62.0
	>2	31	20.7
Parity	Nulliparous	69	46.0
	Multiparous	81	54.0
Birth order	1st order	69	46.0
	2nd order	64	42.7
	3rd and above	17	11.3
Gestation period (in weeks)	Pre-term (<37)	16	10.7
	Term (37-40)	130	86.7
	Post term (>40)	4	2.7
Whether the delivery was CS/vaginal/others	CS	30	20.0
	Normal	120	80.0
If CS whether it was elective/emergency?	Elective	13	43.3
	Emergency	17	56.7

DISCUSSION

The mother and child characteristics data reveals a mean age at menarche for mothers of 12.97 years, aligning with other studies showing a mean age around 13.49 years, reflecting a trend of decreasing menarcheal age in India due to improved health and nutrition.[9,10] The typical marriage age of 21.45 years for mothers in the study is consistent with national data, indicating an increase in the mean age at first marriage from 17.2 years in 2005-06 to 19.2 years in 2019-21, attributed to better educational and economic opportunities for women.[10,11] The average of 1.77 pregnancies and the mean age of 25.27 years at current birth reflect trends seen in national surveys, where the mean age at first birth is around 21 years, suggesting slightly later childbearing ages influenced by family planning and birth spacing.[12] The distribution of birth intervals and birth order in the study is comparable to national data, showing a preference for closer spacing between births in many regions due to cultural practices and family planning access.[10,12]

Additionally, the gestation periods and delivery modes observed in the study, with 20% CSs and 80.0% normal vaginal deliveries, align with national trends, indicating increased caesarean rates, particularly in urban and private healthcare settings.[10,11] These findings collectively reflect broader national patterns in reproductive health and childbearing practices in India, influenced by improved healthcare, education, and socioeconomic conditions. Studies from Uttar Pradesh provide further context: a study from Uttar Pradesh and Bihar found that about 60% of married adolescents had their first child before the age of 20, with a significant proportion experiencing adverse pregnancy outcomes.[13] In rural Uttar Pradesh, 83% of women utilized antenatal care services, though only a small fraction received full ANC.[14] In Uttar Pradesh slums, 48% of women had their most recent birth at a government hospital, 25% at home, and 25% at a private hospital.[15]

The present study's immunization coverage and dropout rates from birth to one year show high initial vaccination coverage but significant dropouts as the schedule progresses. Hep-B and BCG vaccinations have the highest coverage at 99.3%, but this drops to 88.7% for the OPV birth dose. This trend continues for OPV-1 (92.0%), OPV-2 (82.7%), OPV-3 (72.0%), and IPV (68.7%). Similarly, pentavalent vaccine coverage starts high at 91.3% for the first dose, then declines for pent-2 (80.7%) and pent-3 (71.3%), with comparable declines for rotavirus and other vaccines. Compared to other Indian studies, the NFHS-5 (2019-21) reported BCG coverage at 95.2%, OPV0 at 89.0%, OPV-3 at 76.5%, with pent-3 coverage at 79.2%, and Measles at 88.6%. The NFHS-4 (2015-16) showed BCG coverage at 91.9%, OPV0 at 78.4%, and OPV-3 at 72.8%, with pent-3 coverage at 62% and Measles at 81.1%.[16] The DLHS-4 (2012-13) reported slightly lower figures for similar vaccines. Dropout rates in the current study, peaking at 27.3% for IPV and 32.0% for Rota-3, mirror the high dropout trends seen in NFHS-4 and state-specific studies, highlighting the critical need for targeted interventions to maintain higher immunization completion rates.[17,18]

The study detailing vaccination timing for 150 children highlights varying rates of on-time and delayed vaccinations across different immunizations in India. Hepatitis B showed the highest on-time rate at 99.3%, underscoring successful adherence to the recommended schedule. However, Rota-1 experienced the highest delay rate at 35.5%, indicating significant challenges in timely administration. BCG and OPV birth doses also exhibited notable delays, at 15.8% and 25.3% respectively, reflecting gaps in initial vaccine administration. Subsequent OPV doses (OPV-1: 65.9%, OPV-2: 70.2%, OPV-3: 67.6%) and pentavalent vaccines (Pent-1: 73.0%, Pent-2: 77.7%, pent-3: 72.9%) showed moderate on-time rates with corresponding delays. Similarly, MR and Vitamin A vaccinations were on time for approximately 74% and 72% of children, with significant delays observed. These findings are consistent with broader studies indicating challenges in maintaining vaccination schedules in India.[19] For instance, research by Singh et al on NFHS-4 data highlights delays in rotavirus and pentavalent vaccinations, emphasizing regional and socio-economic disparities impacting timely immunization. Addressing these delays requires targeted interventions focusing on healthcare access, education, and awareness to enhance adherence to vaccination schedules and improve overall coverage rates.[20]

This study has some limitations too, including the random selection from a community health centre, which may exclude home or privately-born infants, reflecting selection bias. The short data collection period may miss seasonal variations, and follow-up challenges could lead to incomplete data. The socio-demographic homogeneity of the sample and focus on specific vaccines limit generalizability. Additionally, external factors like healthcare worker availability and vaccine stock-outs were not extensively considered, and the study did not explore the quality of health services or community engagement, which are crucial for vaccination compliance.

CONCLUSION

The study highlights significant challenges in maintaining high immunization coverage and timely administration of vaccines among children in India. While initial vaccination coverage rates, such as those for hepatitis B and BCG, are commendably high, there is a notable decline in subsequent doses, exemplified by the drop in coverage for OPV and pentavalent vaccines. These trends are indicative of systemic issues that hinder consistent vaccine adherence. The findings reflect broader national patterns, aligning with studies like NFHS-5, which show similar coverage and dropout rates. The high on-time vaccination rate for hepatitis B at 99.3% contrasts sharply with the substantial delays seen in Rota-1 and other vaccines, underscoring disparities in healthcare access and awareness. Addressing these gaps is crucial for enhancing the effectiveness of immunization programs and achieving better health outcomes for children.

Recommendations

To enhance immunization coverage and adherence, targeted interventions are necessary, including strengthening healthcare infrastructure in rural and underserved areas, implementing educational campaigns to inform caregivers about timely vaccinations, addressing socio-economic barriers such as transportation and financial constraints, establishing robust monitoring systems to track vaccination coverage, and engaging community leaders to promote immunization and dispel misconceptions. Additionally, proper training of nursing staff on immunization practices is crucial to ensure they are well-equipped with the knowledge and skills needed to administer vaccines correctly and manage any potential complications, thereby improving the overall effectiveness of immunization programs.

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