Child vaccination timing, intervals and missed opportunities in pastoral and semi-pastoral areas in Ethiopia

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Abstract

Background: Immunization is one of the most powerful and cost-effective public health interventions. Most vaccines in the immunization schedule require two or more doses to trigger adequate immune response; appropriate timing, proper interval between vaccine doses, and completion of all vaccine doses are important to attain optimal protection.

Objective: To evaluate and identify factors associated with the timeliness of vaccine doses; assess the interval between vaccine doses; and identify missed opportunities among children aged 12 to 23 months.

Methods: A cross-sectional descriptive study was conducted that employed the 30 by 10 modified WHO immunization coverage cluster sampling technique. Considering pastoral and semi-pastoral areas, a total of 60 clusters with a sample of 600 children aged 12 to 23 months and mothers/caregivers were included. Data were collected using smartphones loaded with the Open Data Kit (ODK) system and exported to STATA 12.0 for data description and analysis.

Results: The response rate was 97%, with 54.8% of the sample from pastoral areas. About 51% of the respondents were Muslim, 68% had no education, and 67% were aged 30 or above. More than one fifth (21.9%) of children received at least one vaccine dose earlier than the recommended minimum age. Nearly half (47.7%) of children received at least one subsequent dose earlier than an interval of four weeks. The overall rate of missed opportunities was 42.7%, which was higher in pastoral (61.4%) compared to semi-pastoral areas (30.9%) (P <0.001). Children from pastoral areas had a higher rate of missed opportunities compared to children from semi-pastoral areas (OR=4.05; 95% CI: 2.28-7.22); and children from mothers/caregivers aged 30 or above had a higher rate of missed opportunities than mothers aged <30 (OR=1.89; 95% CI: 1.32-3.13).

Conclusions: The study identified high proportions of children who started vaccination earlier than the recommended age (later for the first dose of Oral Polio Vaccine (OPV0)). In addition, multiple vaccine doses were administered before the minimum interval of four weeks. Children in pastoral areas have higher rate of missed opportunities compare to children in semi pastoralist and pastoralist areas for vaccines with same schedule.

Recommendations: Strong interpersonal communication between mothers and vaccination providers is vital for the timely administration of vaccines. Emphasis should be placed on regular supervision and periodic in-service training of health workers to practice timely vaccine commencement, and maintain proper intervals between doses. Immunization service providers should give all the recommended vaccines with same schedule to reduce rate of missed opportunities. [*Ethiop J. Health Dev.* 2019; 33(Special issue):16-23]

Key words: Vaccination timing, interval between doses, pastoralist, semi-pastoralist, Ethiopia, CORE Group Polio Project

Introduction

Immunization is one of the most powerful and cost-effective health interventions. It prevents debilitating illness and disability, and saves 2 to 3 million lives every year. Immunization helps to transform lives, giving children the chance to grow up healthy, go to school, and improve their life prospects (1,2). According to the EDHS 2016 report, in Ethiopia, 53% of children received the third dose of pentavalent, 54% received measles vaccine, and 39% were fully vaccinated (3).

The delivery of good-quality and timely vaccination is important to ensure optimum protection. Most vaccines in the immunization schedule require two or more doses to stimulate adequate immune response. To attain optimal protection, vaccines must be administered with appropriate timing, with proper intervals between doses, and all scheduled vaccine doses need to be completed (4).

Different studies identify that timely invalid vaccination practices (i.e. administered at the wrong time) are common and more prevalent in African countries (5). Analysis of data from 31 countries identified timely invalid doses of 12.1%, 5.7%, and 15.5% for Diphtheriae-Tetanus-Pertussis (DTP) 1, DTP 3 and Measles Conjugate Vaccine (MCV) vaccinations, respectively. Of the invalid DTP 1 vaccinations, 7.4% and 5.5% were administered to children younger than 1 week and 2 weeks, respectively (5). A study in two districts in Malawi identified about 9-10% of pentavalent 1 doses were administered before 6 weeks of age and 15% of measles vaccines were administered before 270 days (6).

A study in Uganda identified 10.7% of measles vaccinations were administered earlier than the recommended time (7). A study in two districts of Malawi identified about 7-8% of the pentavalent 3 doses were administered less than 28 days after

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pentavalent 2 (6). In 12 countries, the proportion of invalid DTP 3 vaccinations administered with an interval of less than two weeks before the previous dose varied between 30% and 50%. In the 31-country analysis referred to above, the proportion of MCV doses administered at an age of less than 6 months varied between 20% and 45% (5).

Missed vaccine opportunities contribute to reducing child immunization coverage. Studies in Nigeria and in other 45 African countries found that 32% of eligible children missed opportunities for vaccination. Children who reached the health facilities for vaccination were missed mainly due to the failure to simultaneously administer all eligible vaccines to the child; false contraindications; health workers' practices, including not opening a multi-dose vaccine vial for a small number of children to avoid vaccine wastage; and logistical problems (8,9). A study conducted in rural Nigeria identified more than one quarter (27.4%) of children had two or three missed opportunities for vaccination (8). A study in North Kenya identified maternal level of education, knowledge of vaccine-preventable diseases, and means of transportation to the health facility to have a statistically significant association with child immunization (10).

Although many studies have been conducted to determine vaccination coverage and determinants of child immunization, little is known about timely valid vaccinations and missed opportunities in Ethiopia. Therefore, this study examined the timeliness of child vaccination, the interval between vaccine doses, and missed opportunities of child immunization among children aged 12 to 23 months.

Methods

Study areas: The study was conducted in 80 CGPP implementation *woredas*, which are pastoralist and semi-pastoralist communities, located in Benishangul-Gumuz, Gambella, Oromia, Somali, and Southern Nations, Nationalities and Peoples' regions, in July 2015.

Study design: A cross-sectional descriptive study was employed.

Study population: All children aged 12 to 23 months and their mothers/caregivers residing in CORE Group Polio Project (CGPP) intervention *woredas*.

Sampling procedure: Multistage cluster sampling was employed to identify regions, zones, *woredas* and *kebeles*. All of the 80 CGPP implementation *woredas* were listed with their populations to calculate the cumulative population. Sixty *kebeles*/clusters were selected randomly from 51 *woredas*. The survey implemented the (30 by 10) × 2 modified WHO immunization coverage cluster sampling technique (13). From each selected *kebele*/cluster, 10 households with children aged 12 to 23 months and mothers/caregivers were selected to make the total sample of 600, which was stratified into pastoral and semi-pastoral areas. The data collectors identified the center of the *kebeles* and divided the *kebeles* into four sections (East, West, North and South). 'Bottle spinning' was used to select the first household and the rest of the households were selected based on the principle of 'the next nearest door'. A household with at least one child aged between 12 and 23 months in the center of the selected *kebele* was the initial household to start the interviews. Next, the mothers/caregivers of each eligible child aged 12 to 23 months were interviewed until the sample size was reached. In the event of closed doors or absentees, the next door was visited.

Data collection and management: Face-to-face interviews of mothers/caregivers and child immunization cards at home or at health facilities were used for data collection. Smartphones loaded with Open Data Kit (ODK) were also used for data collection. The data were extracted from the server, cleaned, and exported to STATA version 12 for analysis. Binary logistic regression was used to identify associated factors for children with timely invalid doses and missed opportunities. Odds ratios and 95% confidence intervals (CIs) were determined to measure the effect of each covariate used on the outcome variables.

Ethical considerations: The project baseline, mid-term and final evaluation surveys were part of the project agreement document signed by regional health bureaus. This study was conducted as part of the project's mid-term evaluation. The CGPP Secretariat wrote a letter of collaboration to respective regional, zonal, and w*oreda* health offices; and *woreda* health offices wrote letters to *kebele* offices requesting permission and collaboration. Participation was voluntary, and interviewers obtained verbal informed consent from all respondents.

Operational definitions

Timeliness of vaccination: Vaccine doses administered in accordance with the recommended minimum age, i.e. less than two weeks for OPV 0, after six weeks for the first doses of pentavalent, Pneumococcal Conjugate Vaccine (PCV) and OPV, and after nine months for measles.

Valid interval between doses: Vaccine dose administered after a minimum interval of four weeks from the preceding dose of multi-dose vaccines (pentavalent, PCV, OPV and rotavirus).

Missed opportunity: Where an eligible child attends a vaccination session, but does not receive all the recommended vaccines for their given age.

Results

From the planned sample of 600 children aged 12 to 23 months, complete responses were obtained from 582 (97%) respondents. During analysis, five (0.8%) were excluded due to incomplete data. Of the 3% who were considered as non-respondents, two (0.3%) refused and 16 (2.7%) were not at home during the survey. More than half (54.8%) of the study subjects were

pastoralists and 51.3% were Muslim. About 67% of the mothers/caregivers were younger than 30 years old, 67.9% had no education, and 65% were housewives.

Timeliness of vaccine doses: Vaccination cards and health facility records were sources of information for data collection. Pentavalent 3, OPV 3, measles and full vaccination coverage were 58.8%, 58.6%, 53.6% and 44%, respectively. More than one fifth (21.9%) of children received at least one vaccine dose before the recommended age. The proportion of children who had received early vaccine doses ranged from 32.9% for measles vaccine before the age of 9 months, to 23.8% for rotavirus vaccine before the age of 6 weeks. On the other hand, 24.4% of children received OPV 0 after the age of 2 weeks.

Table 1: **Vaccination timing for different antigens by residence in CGPP implementation areas, July 2015**

Age at	Sample	Residence				P-value
		Semi-pastoral		Pastoral		
		No.	%	No.	%	
OPV 0						
Within two weeks	31	26	83.9	5	16.1	0.777
After two weeks	10	8	80.0	2	20.0	
Total	41	34	82.9	7	17.1	
OPV 1						
Before 6 weeks	90	52	57.8	38	42.2	0.090
6-8 weeks	80	59	73.8	21	26.3	
> 8 weeks	182	116	63.7	66	36.3	
Total	352	227	64.5	125	35.5	
Pentavalent 1						
Before 6 weeks	86	48	55.8	38	44.2	0.047
6-8 weeks	80	59	73.8	21	26.3	
> 8 weeks	196	120	61.2	76	38.8	
Total	362	227	62.7	135	37.3	
PCV 1						
Before 6 weeks	81	49	60.5	32	39.5	0.161
6-8 weeks	71	53	74.6	18	25.4	
> 8 weeks	182	117	64.3	65	35.7	
Total	334	219	65.6	115	34.4	
Rotavirus 1						
Before 6 weeks	50	29	58.0	21	42.0	0.023
6-8 weeks	48	40	83.3	8	16.7	
> 8 weeks	171	121	70.8	50	29.2	
Total	269	190	70.6	79	29.4	
Measles						
Before 9 months	94	60	63.8	34	36.2	0.136
9-12 months	192	136	70.8	56	29.2	
After 12 months	23	12	52.2	11	47.8	

Interval between vaccine doses: The study identified nearly half (47.7%) of the children received at least one subsequent antigen within four weeks. Early administration of the second dose of OPV (11.9%), pentavalent (11.6%) and PCV (11.5%) were higher compared to the third doses of OPV (7.3%), pentavalent (7.5%) and PCV (8.5%).

Table 2: **Time interval of multi-dose vaccines in CGPP implementation areas, July 2015**

Interval between	Residence				Total		P-value
	Semi-pastoral		Pastoral				
	No.	%	No.	%	No.	%	
OPV 2 and OPV 1							
Appropriate	151	68.3	84	73.7	235	70.1	0.412
Early	30	13.6	10	8.8	40	11.9	
Delayed	40	18.1	20	17.5	60	17.9	
Total	221	100	114	100	335	100	
OPV 3 and OPV 2							
Appropriate	152	70.4	85	74.6	237	71.8	0.057
Early	12	5.6	12	10.5	24	7.3	
Delayed	52	24.1	17	14.9	69	20.9	
Total	216	100	114	100	330	100	
Pentavalent 2 and Pentavalent 1							
Appropriate	153	69.9	90	76.9	243	72.3	0.132
Early	31	14.2	8	6.8	39	11.6	
Delayed	35	16	19	16.2	54	16.1	
Total	219	100	117	100	336	100	
Pentavalent 3 and Pentavalent 2							
Appropriate	149	69.6	87	73.7	236	71.1	0.042
Early	12	5.6	13	11	25	7.5	
Delayed	53	24.8	18	15.3	71	21.4	
Total	214	100	118	100	332	100	
PCV 2 and PCV 1							
Appropriate	147	69	85	78.7	232	72.3	0.095
Early	30	14.1	7	6.5	37	11.5	
Delayed	36	16.9	16	14.8	52	16.2	
Total	213	100	108	100	321	100	
PCV 3 and PCV 2							
Appropriate	140	66.7	79	72.5	219	68.7	0.001
Early	13	6.2	14	12.8	27	8.5	
Delayed	57	27.1	16	14.7	73	22.9	
Total	210	100	109	100	319	100	
Rotavirus 2 and Rotavirus 1							
Appropriate	112	65.5	48	70.6	160	66.9	0.571
Early	17	9.9	4	5.9	21	8.8	
Delayed	42	24.6	16	23.5	58	24.3	
Total	171	100	68	100	239	100	

Table 3: **Timely invalid vaccination doses by mothers'/caregivers' characteristics and sex of child in CGPP implementation areas, July 2015**

Characteristics	No	At least one timely invalid dose		P-Value	At least one early first dose		P-value	At least one early interval		P-value
		No	%		No	%		No	%	
Residence										
Semi-pastoral	230	140	60.9	0.275	54	23.5	0.342	115	50	0.268
Pastoral	145	80	55.2		28	19.3		64	44.1	
Educational status										
At least primary level	149	88	59.1	0.900	33	22.1	0.915	75	50.3	0.413
No Education	226	132	58.4		49	21.7		104	46	
Religion										
Islam	150	87	58	0.729	28	18.7	0.145	72	48	0.928
Christianity	200	120	60		51	25.5		96	48	
Others	25	13	52		3	12		11	44	
Age group										
30 and above	110	60	54.5	0.296	23	20.9	0.773	48	43.6	0.306
<30	265	160	60.4		59	22.3		131	49.4	
Occupation										
Housewife	238	144	60.5	0.341	61	25.6	0.020	111	46.6	0.576
Not housewife	137	76	55.5		21	15.3		68	49.6	
Sex of the child										
Male	176	106	60.2	0.564	38	21.6	0.903	86	48.9	0.680
Female	199	114	57.3		44	22.1		93	46.7	
Total	**375**	**220**	**58.7**		**82**	**21.9**		**179**	**47.7**	

Missed vaccination opportunities: An opportunity for immunization is missed when an eligible child attends a vaccination session but fails to receive all the recommended vaccines for that age. The survey identified overall missed opportunities of 42.7% (61.4% among children of pastoralist mothers, compared with 30.9% (P <0.001) among children of semi-pastoralist mothers). Missed opportunities were higher among Muslim mothers (52.7%) compared to mothers who were Christian (35.5%) or practiced other religions (40.0%) (P <0.01). The rate of missed opportunities for Bacillus Calmette-Guerin (BCG) was the highest (17.3%) among children who received at least one vaccine before their first birthday. The missed opportunities for OPV 0, measles and PCV vaccinations were 15.5%, 14.4% and 10.1%, respectively (Table 4, Table 5).

Table 4: **Missed vaccination opportunities by antigen and residence in CGPP implementation areas, July 2015**

Vaccine antigen	Semi-pastoral		Pastoral		Total		P-value
	No.	%	No.	%	No.	%	
BCG	11	4.8	54	37.2	65	17.3	< 0.001
OPV 0	39	17.0	19	13.1	58	15.5	0.315
OPV 1	3	1.3	16	11.0	19	5.1	< 0.001
OPV 2	4	1.7	11	7.6	15	4.0	0.005
OPV 3	8	3.5	7	4.8	15	4.0	0.516
Pentavalent 1	5	2.2	17	11.7	22	5.9	< 0.001
Pentavalent 2	5	2.2	11	7.6	16	4.3	0.012
Pentavalent 3	9	3.9	5	3.4	14	3.7	0.817
PCV 1	11	4.8	27	18.6	38	10.1	< 0.001
PCV 2	10	4.3	21	14.5	31	8.3	0.001
PCV 3	14	6.1	14	9.7	28	7.5	0.200
Measles	16	7.0	38	26.2	54	14.4	< 0.001
At least one missed	71	30.9	89	61.4	160	42.7	< 0.001
Sample size	**230**		**145**		**375**		

Table 5: **Missed vaccination opportunities by mothers'/caretakers' characteristics and sex of child in CGPP implementation areas, July 2015**

Mothers'/caregivers' characteristics and sex of child	Any missed opportunity					P-value
	Yes		No		Total	
	No.	%	No.	%	No.	
Residential area						
Semi-pastoral	71	30.9	159	69.1	230	< 0.001
Pastoral	89	61.4	56	38.6	145	
Age group						
< 30	118	44.5	147	55.5	265	0.258
30 and above	42	38.2	68	61.8	110	
Educational status						
At least primary	56	37.6	93	62.4	149	0.106
No education	104	46.0	122	54.0	226	
Religion						
Muslim	79	52.7	71	47.3	150	0.006
Christian	71	35.5	129	64.5	200	
Others	10	40.0	15	60.0	25	
Occupation						
Housewife	101	42.4	137	57.6	238	0.906
Not housewife	59	43.1	78	56.9	137	
Sex of the child						
Male	71	40.3	105	59.7	176	0.392
Female	89	44.7	110	55.3	199	
Total	**160**	**42.7**	**215**	**57.3**	**375**	

Maternal- and child-related factors associated with timely validity and missed opportunities: Mothers'/caregivers' characteristics were examined to identify associated factors with validity of vaccine doses and missed opportunity. None of the mothers'/caregivers' characteristics were found to be significant in terms of validity of vaccine doses. Higher missed opportunities were observed among children of pastoralist mothers compared to semi-pastoralist mothers (OR=4.05; 95% CI: 2.28-7.22), and children from mothers/caregivers aged 30 and above had a higher rate than those aged < 30 years (OR=1.89; 95% CI: 1.32-3.13).

Table 6: **Mothers'/caregivers' characteristics and sex of child for timely invalid vaccination and missed opportunities**

Mothers'/caregivers' characteristics and sex of child	Timely invalid doses			Missed opportunity		
	OR	95% CI for OR		OR	95% CI for OR	
Residence (Semi-pastoral)						
Pastoral	0.79	0.46	1.35	4.05	2.28	7.22
Education (No education)						
Primary or above	1.07	0.68	1.68	1.32	0.82	2.11
Religion (Islam)						
Christianity	0.96	0.55	1.67	1.04	0.58	1.87
Others	0.82	0.33	2.02	0.63	0.24	1.66
Sex of the child (Male)						
Female	0.89	0.59	1.35	1.28	0.83	1.98
Age of mother/caregiver (< 30)						
30 and above	1.27	0.79	2.04	1.89	1.32	3.13
Occupation (Housewife)						
Not housewife	0.83	0.52	1.30	0.94	0.58	1.52
Constant	1.90	1.03	3.51	0.42	0.14	1.25

Discussion

Immunization is one of the most cost-effective and impactful public health interventions available for reducing morbidity and mortality of children. However, this impact can be diminished if vaccines are not administered according to prescribed timing and at proper intervals. Failing to do so can result in less than adequate immunity (4). This study showed that a substantial percentage of children in the study areas did not receive vaccines at the proper time or with the proper spacing of doses. The study also found that practitioners have missed opportunities to administer vaccines to children – 42.7% of children attended

vaccination sessions, but did not receive all the prescribed vaccinations.

It is known that vaccine administration before the recommended starting age for scheduled doses can result in suboptimal immune response due to pre-maturity of the immune system (4). Nearly half (47.7%) of the children in this study received at least one vaccination dose before the recommended age. These results support the findings of other studies: a study in Uganda showed that 10.7% of measles vaccines were administered early (7); a study conducted in 31 African countries identified that in 13 of the countries, the proportion of MCV doses administered to children younger than 6 months varied between 20% and 45%. Of the invalid DTP 1 vaccinations, 7.4% and 5.5% were administered to children less than one and two weeks' old, respectively (5). Similarly, in Nigeria, 6.8% of the children received measles vaccination before the age of 9 months (11). A study in two districts of Malawi identified 9-10% and 3-5% of children received pentavalent 1 and rotavirus 1 vaccines, respectively, before 42 days of age (6). In addition, a study in Uganda identified 10.7% of measles vaccinations were administered earlier than the recommended time (7).

A substantial proportion (21.9%) of children received at least one dose of an antigen earlier than 4 weeks. Similar findings were revealed in studies conducted in different countries. A study conducted in 31 African counties identified invalid doses of 12.1%, 5.7%, and 15.5% for DTP 1, DTP 3 and MCV vaccinations, respectively. In 12 countries, the proportion of invalid DTP 3 vaccinations administered – with an interval of less than two weeks before the preceding dose – varied between 30% and 50% (5). A study in two districts of Malawi identified about 7-8% of pentavalent 3 doses were administered less than 28 days after pentavalent 2 (6).

An opportunity for immunization is missed when a child who is eligible and attended vaccination session but does not receive all the required vaccines. The overall proportion of missed opportunities was 42.7% – the proportion was higher among children of pastoralist mothers (61.4%) compared with children of semi-pastoralist mothers (30.9%) (P <0.001). The findings from other studies reveal similar results. For example, a study in Nigeria identified a total of 33.4% missed vaccination opportunities. About 27.4% of the children had two or three missed opportunities for vaccination and 69.2% of the children could have completed their vaccination schedule if they had not missed the opportunity for measles vaccination. Children with missed opportunities for vaccination are more likely to have an incomplete vaccination status than children with no missed opportunities (8). Studies from 45 (developing and industrialized) countries identified 32% (range, 0-99%) of the children and women of childbearing age had missed opportunities during visits to health facilities for immunization or other reasons (9). Missed opportunities were mainly due to the failure to administer simultaneously all vaccines for which a child was eligible; false contraindications; health workers' practices, including not opening a multi-dose vaccine vial for a small number of people to avoid vaccine wastage; and logistical problems (9).

Mothers'/caregivers' characteristics were analyzed using logistic regression to pinpoint associations between the validity of vaccine doses and missed opportunities. This study found no significant association between caregivers' characteristics – such as residence, education, religion, age and occupation – and validity of vaccine doses. This is at variance with the findings of other research studies, which found strong associations between the validity of vaccine doses and mothers'/caregivers' socio-demographic characteristics. Several prior studies illustrate the association between socio-demographic variables and vaccination timing and missed opportunities. A study in Kampala identified increasing numbers of children per woman (AOR=1.84, 95% CI: 1.29-2.64), non-delivery at health facilities (AOR=1.58, 95% CI: 1.02-2.46), being unmarried (AOR=1.49, 95% CI: 1.15-1.94) or being in the lowest wealth quintile (AOR=1.38, 95% CI: 1.11-1.72) were significantly associated with vaccination timing (7). Another study conducted in the USA on timeliness of childhood immunization revealed that having more children in the household, mothers younger than 30 years, use of public providers, and multiple vaccination providers have significant associations with timely vaccination (11). A study in Gambia also identified a significant association between un-timeliness of vaccination and the type of occupation of mothers, place of birth and mode of transportation to the health facilities (12). There are a number of possible explanations for the lack of association between socio-demographic factors in this study. For example, if mothers bring their children earlier than the minimum age or interval, it is the providers' role to advise the mother to return when their child has reached the recommended age and not to give the vaccines earlier than the recommended age/interval.

Conclusions

Giving vaccines to an infant who is too young (later of OPV 0), or not leaving a large enough gap between doses, can result in a sub-optimal immune response.

Children who received vaccinations earlier than the recommended age (later for OPV 0) and before the minimum interval of four weeks were found to be higher, this may result a suboptimal immune response.

Vaccine administration before the recommend minimum age and maintaining the minimum time interval between successive doses were the main concerns of immunization programs in the study areas. Mothers'/caregivers' characteristics have no significant association with invalid timeliness of vaccine doses. However, missed vaccination opportunities among children residing in pastoral areas are much higher than for children in semi-pastoral areas.

Recommendations

- Strong interpersonal communication between mothers and vaccination service providers is

vital to remind mothers of the timely receipt of vaccines.

- Social and behavioral change communication strategies are needed to educate and engage mothers on the importance of appropriate commencement of vaccination and adhering to the recommended time intervals between doses.
- Regular supervision and periodic in-service training of vaccination service providers is needed to enhance their understanding of the importance of timely vaccine commencement, and maintaining prescribed intervals between consecutive doses.
- Immunization service providers should be encouraged to maintain stocks of the required amount of vaccine doses and administer all the recommended antigens to reduce missed vaccination opportunities.
- Further research is needed to understand the reasons behind the high numbers of missed vaccination opportunities, inappropriate vaccine commencement, and incorrect spacing of vaccines doses. Further efforts and research are also required to assess the readiness of immunization service providers.

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