Digitalized to reach and track: a retrospective comparison between traditional and conditional estimate of vaccination coverage and dropout rates using e-Tracker data below one-year children in Bangladesh during-COVID and pre-COVID period

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Summary

Background With an impressive track record in expanding childhood immunization and an inclination to adopt digitalization in healthcare service delivery, Expanded Program on Immunization (EPI) Bangladesh piloted the e-Tracker intervention in Moulvibazar district and Dhaka South City Corporation (Zone-5) from 2019 till the end of 2021.

Methods We retrieved and analyzed the digitalized e-Tracker data of 114,194 infants born between January 1, 2019 and December 31, 2020, with help from Health Management Information System (HMIS) and UNICEF Bangladesh. Childhood vaccination coverage and dropout rates were determined using a 'Traditional approach' traditionally used by WHO and a 'Conditional technique' with a modified denominator. Using a multiple logistic regression model, we examined the effects of COVID-19, birth-cohorts, mother education, and location on vaccination rates (coverages & dropouts) to aid with informed decision-making by the policymakers.

Findings The conditional estimation method yielded a lower full vaccination coverage during pre-COVID period than the national and global reported coverage derived using the 'traditional method' (73.4% vs. 89.0% & 81.0%). As expected, while the coverage has decreased, the dropout rate increased "during-COVID" compared to the "pre-COVID" period. However, dropouts were estimated lower in the 'conditional method.' The average age (in months) for getting BCG was higher in Moulvibazar (~2.5 months) than that in Dhaka (~1.4 months). All birth-cohorts from 'the during-COVID period had about 30% lower odds of getting fully vaccinated than those from the 'pre-COVID' period.

Interpretations Age-cohort-specific analysis showed a decline in coverage rates before and during COVID, but e-Tracker didn't have enough data to draw additional conclusions. The server only stored the child's gender, the caregiver's monthly salary, and the mother's education. It didn't track any other factors related to dropout rates. The e-Tracker is an excellent tool for measuring real coverage and should be scaled nationwide.

Funding UNICEF, Bangladesh.

Keywords: Childhood vaccination; Immunization coverage; Vaccination coverage; Traditional estimate; Conditional estimate; Dropout rates

Introduction

Routine immunization for children is a proven strategy for reducing childhood mortality and morbidity[1–3]; however, approximately 23 million children remain unvaccinated and succumb to death due to vaccine-preventable diseases every year globally.[4] In Bangladesh,

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Research in context

Evidence before this study

We searched PubMed for articles published up to December 31, 2021. We used search terms ((childhood) AND (immunization coverage)) AND (Bangladesh)) without language restrictions. The search yielded several studies from 1997 to 2021 and that focused on generating childhood immunization coverage and predictors for better coverage. Studies used secondary data sources like Bangladesh Demographic Health Survey (BDHS) data and some data derived from national coverage evaluation survey reports. However, when we added search terms like "AND (mHealth)" and "AND (e-Tracker)"; the search yielded zero results. Existing studies also looked into vaccine acceptance patterns among the general population and the role of different community-based health service delivery mechanisms.

Added value of this study

This is the first study of its kind investigating childhood vaccination coverage and dropout rates estimation using individualized data source like e-Tracker in Bangladesh. The study analyzed the data for 114,194 children enrolled in Moulvibazar and Dhaka South City Corporation (Zone-5) in Bangladesh from January 2019 to December 2021. This is also the first study that looked into vaccination coverage and dropout trends for children aged below one year before and during the COVID-19 pandemic. We report on childhood vaccination coverage and dropout rates using a 'conditional method', which was possible because of the existence of individualized child data recorded in the e-Tracker platform. The study findings show how the immunization coverage would seem if estimated using a modified and updated denominator. It also accurately reports the decline in coverage rates and the increase in dropout rates during the COVID-19 pandemic in Bangladesh.

Implications of all the available evidence

Childhood immunization coverage is usually estimated using aggregated data and is often plagued with faulty denominators in countries like Bangladesh. The e-Tracker system can be a valuable source of child immunization-related data generation and estimation, allowing for more accurate coverage estimation and pinpointing adverse scenarios. The e-Tracker can be used to identify gaps between children receiving up-to-date vaccines and those receiving age-appropriate vaccine doses on time, and to calculate dropouts from the registry.

the Expanded Programme on Immunization (EPI) governs one of the most successful routine immunization programmes for children under five years of age[5] by vaccinating approximately 3.7 million children under the age of one year against ten vaccine-preventable diseases and significantly reducing infant and young child mortality.[6]

One of the critical elements for a successful routine immunization programme is the collection of quality immunization data, which can then be used to update the programme.[7] Although there have been several calls for improving data availability and quality to help the policymakers' informed decision-making process, it remains a challenge for the Lower Middle-Income Countries (LMIC).[8] Like many other LMIC countries, EPI Bangladesh uses the paper-based method for routine immunization coverage data reporting. Paper-based reporting is often plagued with challenges like inaccurate data, reliance on faulty denominators (like using the approximate number of targeted children for vaccination in that area) for coverage estimation, and a need for real-time monitoring support for frontline workers.[9]

At the global level, it is apparent that retaining current immunization coverage is a significant challenge for many governments, given the competing priorities.[10] Evidence generated from Latin America, Africa (Tanzania and Zambia), and South Asia (India and Pakistan) showed that digital interventions aided in better surveillance, creating valuable data insights for informed policy reformation.[9,11–15]

Bangladesh is not far behind in piloting digital technology to track new mothers and children.[16] EPI e-Tracker is one such digital-based tracking initiative for immunization in Bangladesh, and it uses the DHIS-2 platform and possesses similar characteristics to the e-Tracker system implemented in Ghana[17] and 'Zindegi Mehfooz' (Safe Life, ZM) from Pakistan.[9,18] With support from UNICEF, EPI Bangladesh implemented the e-Tracker pilot in Moulvibazar (MOULV) district and Dhaka (DHK) South City Corporation in May 2019. The first area is considered rural, while the other is part of the urban settlement.

Although digital modifications have been introduced in immunization-related data acquisition, reporting, and monitoring, attempts that look specifically into properly using the collected data are scarce. Our study used real-time, individual-level data retrieved from the e-Tracker system in calculating vaccination coverages, dose timeliness, and dropout for children under one year of age, which may aid with informed decision-making by the policymakers and possibly solve the denominator problem. We further explored the pre-COVID and during-COVID scenarios for immunization with the e-Tracker data.

Methods

"EPI e-Tracker" pilot programme in Bangladesh

In Bangladesh, the childhood vaccination strategy includes giving every eligible child (from birth to 15

months) one dose of BCG, three doses of Oral Polio & Pentavalent, and one dose of the Measles and Rubella vaccine. A child is considered completely vaccinated if they receive all the required vaccine doses within due time.[6] EPI, Bangladesh, implemented the e-Tracker project as a pilot demonstration for assisting with the vaccination program. With technical help from UNICEF Bangladesh, the pilot began in Moulvibazar and Dhaka South City Corporation (Zone-5) in 2019. The objective of the pilot project was to digitalize the study area's vaccination data collection and the system of reporting coverage rates over time. EPI concentrated its efforts on children under one year of age and permanent inhabitants of the study regions who attended its various vaccination sites for regular immunization services. Vaccinators used a tablet device to update vaccination records on the server. Once registered in the e-Tracker platform, each child was assigned a unique identification number that enabled them to be located later from anywhere in the country. Apart from vaccination status, the vaccinators gathered other related information, such as the father's name, mother's name, home address, mobile number, child's birth registration number, child's gender, etc., for the e-Tracker platform.

Extracting data from the e-Tracker system

We obtained data from the EPI e-Tracker platform, jointly operated and managed by EPI and HMIS, Bangladesh.[1] The data were collected as part of a more extensive implementation study to assess the performance of the EPI e-Tracker pilot project. Children born between January 1, 2019 and December 31, 2020, are included in this analysis, and the corresponding data are extracted from the e-Tracker system. The authors were granted access to the data by HMIS, Bangladesh, with support from UNICEF.

Data management and analysis

The e-Tracker data were imported into statistical software R[19] for cleaning and performing statistical analysis. We computed dropout rates for different birth cohorts using the "traditional method"[4] and a new method as well; we call the new method as the "conditional method." We calculated the vaccination coverage using the "conditional method" only. A multiple logistic regression model was also considered to obtain a complete coverage rate after adjusting for birth cohort, location, and maternal education.

Birth-cohort-specific analysis

To assess the effect of COVID-19 on vaccination coverage rate, we defined eight birth cohorts, which are January-2019 (for births between 1 January 2019 and 31 March 2019) and April-2019 (for births between 1 April 2019 and 30 June 2019), and so on. We tried to follow the children's vaccination schedule for the whole year once they got enrolled into the system; hence, the last cohort for analysis became October-2020 (for births between October 2020 and December 31, 2020), whose full vaccination would finish by October–December 2021.

Operational definitions

Traditional dropout rate

Traditional estimates of dropout rates for vaccine coverage are based on the difference between the number of vaccinations of the first and the last vaccines, which can be defined as

$$= 100\ (\text{`}\ \#\textit{children received the initial vaccine}) \\ \frac{-(\#\textit{children received lastending vaccine})}{(\#\textit{children received the initial vaccine})}$$

For example, the dropout rate for the vaccines "BCG to Penta-2" is defined as

$$= 100\,(\#\textit{children received BCG}) \\ \frac{-(\#\textit{children received Penta–2})}{(\#\textit{children received BCG})}$$

The traditional estimate does not take into consideration whether a child received intermediate required vaccines or not, e.g., whether a child received Penta-1 or not does not affect the estimate of "BCG to Penta-2".

Conditional dropout rate

Conditional estimates of dropout rates consider whether a child received the intermediate vaccines or not. For example, the conditional estimate of dropout rates for vaccines "BCG to Penta-2" is defined as,

$$= 100–100\,\#\textit{children received dosage of} \\ \frac{(\textit{BCG, Penta–1, Penta–2 and Penta–3})}{\#\textit{children received dosage of}} \\ (\textit{BCG and Penta–1 and Penta–2})$$

$$= 1–\textit{Conditional Vaccine Coverage}\,(\textit{CVC})$$

Ethics approval

We acquired the ethical approval for conducting the whole research from the BRAC JPGSPH IRB (Approval ID: IRB-10 April'21-007). A formal request for access to the e-Tracker data for the years examined was submitted to HMIS, DGHS. Given that this was retrospective research using secondary data typically acquired by the e-Tracker program and no identifying personal information was accessible, informed permission from patients was considered unnecessary.

Role of funding source
The funder in this study had no role in the study design, data collection, analysis, interpretation, or writing of the paper.

Results

Background information of the target population derived from e-Tracker
A total of 259 observations are excluded from the analysis because of inconsistent entries (e.g., a birth date is later than the vaccination date, vaccinated after 1-year of age, etc.) or missing BCG vaccination date. In the final analysis, we included 114,194 infants. The Penta-2 data set of the Dhaka site has "birth date" and "e-registration" interchanged for some entries, which were excluded before analyzing the data. Finally, 114,194 children were considered for the analysis in this study. More than 50 percent (50.8%) were male, and 73.7% were from the Moulvibazar district. In addition, 37.9% of the mothers were at most primary educated. Moreover, most children's households earned more than 10K BDT monthly (36.8%) (Table 1).

Birth-cohort specific complete vaccination coverage (CVC) among children
Overall, 68.7% of children are completely vaccinated, i.e., received all the scheduled vaccines, while more completely-vaccinated children are found in Moulvibazar than in Dhaka (76.1% vs. 48.2%). During pre-COVID period the full coverage was 73.4%, while during-COVID period, it went down to 64.6%. The birth-cohort-specific analysis shows that the vaccination coverage was highest for the children of the "January-2019" cohort, and it constantly went downward for the children from the later cohort (Table 2).

Assessing the dose timeliness for acquiring different vaccines
The average age at vaccination is about 2.2 months for BCG, and about one-fourth of children receive BCG after 2.7 months. Children received subsequent first, second, and third dose vaccines (for Penta, OPV, and PCV) between the ages of 2.5–5.5 months. The average age (in months) for getting BCG was higher in Moulvibazar (~2.5 months) compared to that Dhaka (~1.4 months). Fig. 1 shows the age (in months) of receiving different vaccines by site and type.

Vaccination dropout rates by birth cohorts
More than 5% of children who received the BCG vaccine missed the Penta-1 vaccine, and we call this dropout rate "BCG to Penta-1", and the dropout rate increased to about 30% for "BCG to MR-1". The dropout rates for "Penta-1 to Penta-3" and "Penta-1 to MR-1" are slightly over one-tenth and slightly below one-third, respectively. The "Penta-3 to MR-1" dropout rate is about 18% (Table 3).

Area-wise distribution of dropout rates
Using the traditional method
Dropout rates increased over the birth-cohort for all sequences of vaccines (Table 4). Dropout rates increased for children when they were considered to complete multiple vaccine doses (BCG; OPV 1 & 2; Penta 1, 2 & 3; and MR1) sequentially, starting from the initial BCG dose to the final dose of MR1. For example, the dropout for "BCG to Penta-1" sequence in Dhaka for the January-2019 birth cohort was less than the dropout rate of the sequence "BCG to MR1" in the same cohort (11.9% vs. 41.3%). Similar scenarios can be seen for all the vaccine cohorts and sequences. In addition, more dropouts were observed among the birth cohorts starting vaccination 'during-COVID' (Table 4).

Using a conditional method
The dropout rates, estimated using conditional method, are found to be higher among children from Dhaka compared to that of from Moulvibazar (Table 4). However, as expected, the dropout rates increase with the length of vaccine sequence, e.g., the most extended vaccine sequence (BCG to MR1) corresponds to the highest dropout rate and conditional dropout rates are found to be higher among children born in 'during-COVID' compared to the 'Pre-COVID' (Table 5).

Estimation of predictors to complete vaccination of children
Except for the child's gender, all the predictors considered in the multiple logistic regression model significantly affect the probability of full vaccination. The odds of being full-vaccinated are about 30% lower for the April-2019 birth-cohort than that of the January-2019 birth cohort. Note that children from all other birth-cohorts have significantly lower odds of being full-vaccinated than the January-2019 birth-cohort. The odds of being fully vaccinated for children of the Moulvibazar site is 3.5 times that of the Dhaka site. Maternal education significantly affects the odds of complete vaccination as children of mothers with at least higher secondary education have more odds of being fully vaccinated compared to mothers with at most primary education (Table 6). There is no significant difference in odds of full vaccination among children of mothers with at most primary and secondary education.

Discussion
Child-specific vaccination data was accessible because of the e-Tracker system, and it enabled us to investigate the three important aspects of immunization-related estimates: immunization coverage, dose timeliness for children under one year of age, and dropout rates. Factors affecting the dropout rates could also be identified.

n	Overall	Birth-cohorts							
		Jan-2019	Apr-2019	Jul-2019	Oct-2019	Jan-2020	Apr-2020	Jul-2020	Oct-2020
	114,194	14,228	11,827	14,388	16,013	13,882	12,189	15,143	16,524
Child's gender, male	57,873 (50.8)	7074 (49.8)	6113 (51.7)	7403 (51.6)	8170 (51.1)	7023 (50.7)	6187 (50.8)	7588 (50.2)	8315 (50.4)
Mother's education									
Primary or less	43,307 (37.9)	6299 (44.3)	4823 (40.8)	5719 (39.8)	6158 (38.5)	5110 (36.8)	4343 (35.6)	5181 (34.2)	5674 (34.3)
Secondary school certificate (SSC)	40,985 (35.9)	4988 (35.1)	4237 (35.8)	5003 (34.8)	5715 (35.7)	4966 (35.8)	4350 (35.7)	5568 (36.8)	6158 (37.3)
Higher secondary school certificate (HSC)	23,594 (20.7)	2458 (17.3)	2210 (18.7)	2816 (19.6)	3199 (20.0)	3044 (21.9)	2740 (22.5)	3442 (22.7)	3685 (22.3)
Above HSC	6288 (5.5)	472 (3.3)	552 (4.7)	846 (5.9)	941 (5.9)	762 (5.5)	756 (6.2)	952 (6.3)	1007 (6.1)
Intervention site, Moulvibazar (MOULV)	84,159 (73.7)	11,102 (78.0)	8808 (74.5)	10,241 (71.2)	11,749 (73.4)	10,608 (76.4)	8841 (72.5)	10,760 (71.1)	12,050 (72.9)

The results are shown in number (percentage) format.

Table 1: **Distribution of background variables by birth cohort.**

Vaccine sequence	Birth-cohorts								
	Pre-COVID era				During-COVID era				Overall
	Jan-2019	April-2019	July-2019	Oct-2019	Jan-2020	April-2020	July-2020	Oct-2020	
BCG to MR1 (FVC)	11,205 (78.75)	8437 (71.34)	10,118 (70.32)	11,743 (73.33)	9682 (69.74)	8374 (68.70)	9585 (63.30)	9362 (56.66)	78,506 (68.70)
BCG to Penta-3	1281 (9.00)	1835 (15.52)	2116 (14.71)	1642 (10.25)	2042 (14.71)	1692 (13.88)	2709 (17.89)	3704 (22.42)	17,021 (14.90)
BCG to Penta-2	529 (3.72)	505 (4.27)	779 (5.41)	816 (5.10)	648 (4.67)	672 (5.51)	836 (5.52)	1280 (7.75)	6065 (5.30)
BCG to Penta-1	495 (3.48)	457 (3.86)	737 (5.12)	801 (5.00)	734 (5.29)	750 (6.15)	1142 (7.54)	1355 (8.20)	6471 (5.70)
Only BCG	718 (5.05)	593 (5.01)	638 (4.43)	1011 (6.31)	776 (5.59)	701 (5.75)	871 (5.75)	823 (4.98)	6131 (5.40)

Table 2: **CVC by the sequence of different vaccines and birth cohort.**

Coverage estimation using e-Tracker

The data obtained from the e-Tracker system can be a valuable source of child immunization-related data generation and estimation in the upcoming days. Dolan et al. (2019) stated that an electronic immunization registry increases the likelihood of generating more accurate immunization coverage at the individual level and allows estimates to be segregated depending on location and age-cohorts. The discrepancies found in the e-Tracker dataset complement the first claim as it allowed us to check the immunization data entry system more efficiently. Also, we could assess the immunization coverage using age cohorts from the e-Tracker data.

Our study found that full vaccination coverage (FVC) was lower than the reported national and global coverage.[4,6] While electronically gathered databases can retain individually accessible and child-specific vaccination data,[2,9,17,18] most nations rely on aggregately reported data, which has long been challenging in establishing accurate immunization coverage estimates.[11] Especially using a faulty denominator, like an approximate number of children expected to receive the specific vaccine dose in a given month for coverage calculation, can produce overestimated coverages.[20] EPI is a true inspiration in Bangladesh's public health history[6] and has provided good numbers in coverage estimation for a long time compared to other nearby nations. The disparity between our calculated FVC and the nationally reported FVC, on the other hand, confirms the argument of a 2013 US-based study[21] that modifying the denominator for determining coverage can reveal inconsistencies with the standard technique of coverage calculation.

The multiple logistic regression model estimates show that children of the 'pre-COVID' birth-cohorts were fully vaccinated at a higher rate than 'during-COVID' birth-cohorts. More children would be under FVC if they lived in rural areas (Moulvibazar). Child immunization took a great dive backward for the children of 'during-COVID' birth-cohorts due to the widespread lockdowns and fear of getting infected.[22,23] Our estimates with e-Tracker data match the claim with a more accurate portrayal. As a large number of families in the Dhaka region returned to their hometowns or villages due to the widespread lockdowns and the fear, it may have been attributed to the increased chance of children from Moulvibazar getting vaccinated with their more stable population and a bigger area coverage compared to that of the Dhaka region. On the other hand, pinpointing the adverse scenario more efficiently using the electronic registry can be a great tool for quick decision-making for policymakers.[14] The e-Tracker can become one such tool for Bangladeshi policymakers if its operation can be extended to the whole country.

One shortcoming with our e-Tracker data coverage estimation can be attributed to the project's trial phase.

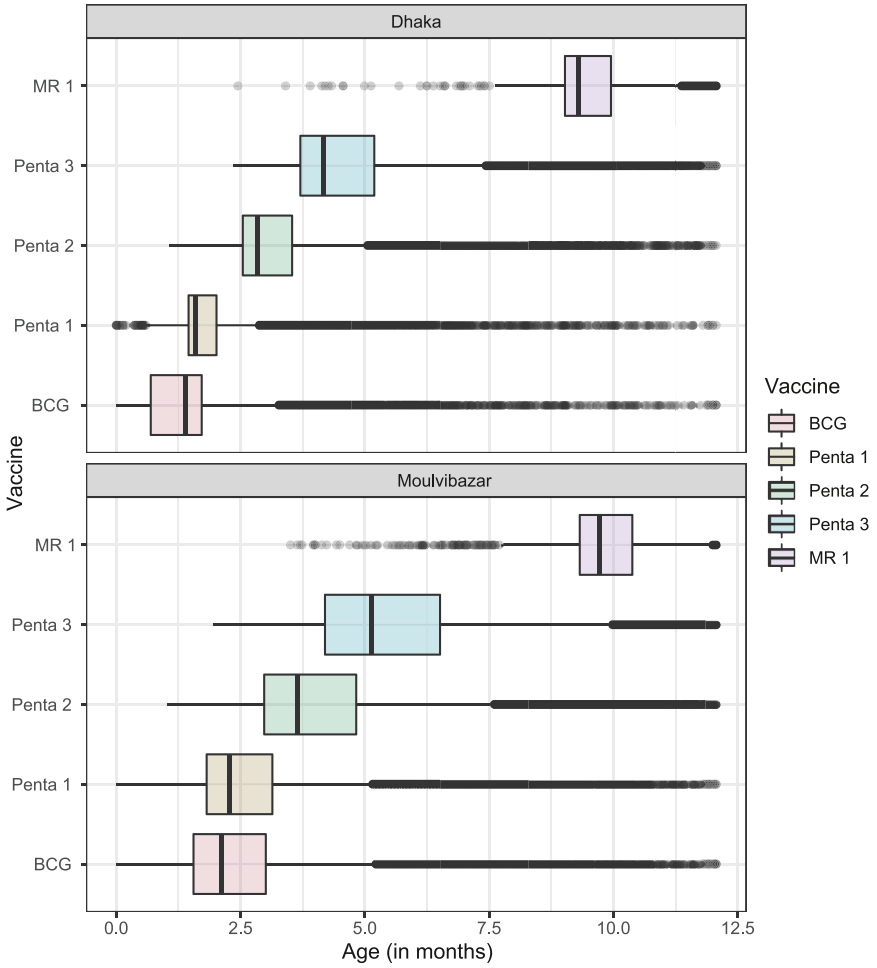

Fig. 1: Distribution of age (in months) at receiving different vaccines by site.

As a result, we could not determine whether the children who began but still needed to complete their vaccinations obtained the missing doses elsewhere. This can be attributed to the significantly higher mobility rate caused by COVID from and within Dhaka[24] and e-Tracker being piloted in two specific regions with no provision to follow up on those who missed vaccine doses due to their mobility. We also cannot claim that the e-Tracker captured 100% of the birth-cohort data. Although all most all children receive vaccination from governmental vaccinators or at government-run facilities, a few children possibly receive the vaccination from private health facilities, which was not covered by the e-Tracker system.

Vaccination dose-timeliness

Vaccine dose timeliness guarantees that a child receives the proper doses on time to avoid vaccine-preventable

Vaccine sequence	Dropout rates					
	Traditional estimates			Conditional estimates		
	DHK	MOULV	Overall	DHK	MOULV	Overall
BCG to Penta-1	12.71	2.75	5.37	12.71	2.75	5.37
BCG to Penta-2	21.93	7.15	11.04	10.57	4.52	5.99
BCG to Penta-3	29.84	11.53	16.35	10.12	4.73	5.97
BCG to MR-1	51.78	23.93	31.25	31.28	14.01	17.82

Table 3: **Different dropout rates for different types of vaccine sequence.**

Vaccine sequence	Pre-COVID period								During-COVID period							
	Jan-19		Apr-19		Jul-19		Oct-19		Jan-20		Apr-20		Jul-20		Oct-20	
	DHK	MOULV	DHK	MOULV	DHK	MOULV	DHK	MOULV	DHK	MOULV	DHK	MOULV	DHK	MOULV	DHK	MOULV
BCG to Penta-1	11.96	3.10	11.20	2.90	11.02	1.77	12.01	4.25	14.17	2.94	12.46	3.21	14.17	2.32	14.15	1.58
BCG to Penta-2	16.48	6.29	16.89	6.13	19.17	5.66	21.60	7.58	25.14	6.48	22.91	7.74	25.94	8.14	25.03	8.78
BCG to Penta-3	21.79	9.56	23.25	9.68	28.72	9.40	30.14	11.43	31.55	10.61	32.08	11.87	33.06	13.01	34.56	15.87
BCG to MR-1	41.33	15.59	50.51	21.17	55.25	19.32	47.05	19.27	48.66	24.58	51.82	23.53	53.84	29.72	61.47	36.61

Table 4: **Traditional estimates of dropout rates for different vaccine sequences and birth cohort.**

Vaccine sequence	Pre-COVID period								During-COVID period							
	Jan-19		Apr-19		Jul-19		Oct-19		Jan-20		Apr-20		Jul-20		Oct-20	
	DHK	MOULV	DHK	MOULV	DHK	MOULV	DHK	MOULV	DHK	MOULV	DHK	MOULV	DHK	MOULV	DHK	MOULV
BCG to Penta-1	11.96	3.10	11.20	2.89	11.02	1.77	12.01	4.25	14.17	2.94	12.46	3.21	14.17	2.32	14.15	1.58
BCG to Penta-2	5.12	3.29	6.42	3.33	9.16	3.97	10.90	3.48	12.78	3.64	11.94	4.68	13.72	5.96	12.68	7.32
BCG to Penta-3	6.36	3.49	7.65	3.79	11.81	3.96	10.89	4.16	8.57	4.42	11.90	4.48	9.61	5.30	12.70	7.77
BCG to MR-1	24.99	6.67	35.52	12.72	37.21	10.95	24.20	8.85	24.99	15.63	29.07	13.23	31.05	19.21	41.12	24.66

Table 5: **Conditional estimates of dropout rates for different vaccine sequences and birth cohort.**

Predictors	Estimate	*p*-value	OR*	95% CI of OR	
				Lower	Upper
Birth cohort					
Jan-2019 (ref.)					
April-2019	−0.378	<0.001	0.686	0.647	0.727
July-2019	−0.387	<0.001	0.679	0.642	0.718
Oct-2019	−0.259	<0.001	0.772	0.731	0.816
Jan-2020	−0.495	<0.001	0.609	0.576	0.644
April-2020	−0.492	<0.001	0.611	0.577	0.648
July-2020	−0.732	<0.001	0.481	0.456	0.508
Oct-2020	−1.056	<0.001	0.348	0.330	0.366
Locations					
Dhaka (ref.)					
Moulvibazar	1.261	<0.001	3.528	3.427	3.632
Child gender					
Female (ref.)					
Male	−0.017	0.206	0.983	0.958	1.009
Maternal education					
Primary (ref.)					
Secondary	0.026	0.099	1.026	0.995	1.058
Higher secondary	0.090	<0.001	1.094	1.055	1.135
Above higher secondary	0.162	<0.001	1.176	1.108	1.247
Constant	0.382	<0.001			

Asterix (*) signed abbreviation depicts Odds Ratio (OR).

Table 6: **Estimate of regression model considered for complete vaccination.**

illnesses (VPD).[20] Yet, it is not typically recorded with the regular EPI reporting system. The age distribution of getting different vaccination doses is compared in our analysis. We were able to track this variation since the e-Tracker generated individual-level data. Using an electronic immunization record allowed governments to identify gaps between children receiving up-to-date vaccines and children receiving age-appropriate

vaccine doses on time.[25] However, the effective use of the dose timeliness will primarily depend on the operational definition imposed by certain countries' EPI, with some modifications, such as adding a buffer period to the predicted date of vaccination. The dose timeliness can also benefit programs in tracking performance.[20]

Calculating the dropouts using e-Tracker

Our analysis showed that dropouts were higher for 'during-COVID' birth-cohorts than for 'pre-COVID' birth-cohorts. While, in general, the reasons for dropouts can be attributed to the perceived quality of health services, social norms, or hesitancy to get the children vaccinated for fear of side effects, COVID-19 may have added further barriers due to the implementation of its preventive measures, supply chain challenges, and disrupted outreach services.[26] There were also differences between the traditional method of dropout rate calculation with the proposed conditional method. Using electronic registers for immunization reporting has become a trend in the LMICs; however, they mostly focus on the creation and testing of new applications like 'Zindegi Mehfooz' and maintaining of dashboards with summary results.[9,18] The individual-level data gathered using those electronic platforms can assist decision-makers and program managers make better decisions. They can be used as performance indicators if the generated data are evaluated well beyond the usual means reported by EPI.[27]

One such area that the program managers can focus on besides immunization coverage is calculating the dropouts from the registry. Electronic registries like the e-Tracker can be modified to track children who did not receive their scheduled doses.[20,27] Also, generating an individual-level database opens up the possibility of analyzing the data in different methods, as we did for our analysis, and this information can be used to generate informed evidence for the policymakers and EPI managers to set their focus on the areas that need more improvement. For example, policymakers can develop specific awareness program policies focusing on the higher dropout rate of particular vaccine doses. The EPI managers could train the vaccinators to emphasize the importance of continuity of vaccination of those doses to caregivers.

As e-Tracker was piloted in only two places, we cannot generalize our results for the whole population. We had to select the two areas as this study was part of broader evaluation research. Hence, the researchers admit that the results might not be the same if done for all child populace in Bangladesh, or it would not be appropriate to make a generalized statement based on the study's findings only. Furthermore, while income status could be a great predictor for coverage estimation, the e-Tracker only had predefined categories of the income variable, along with most observations found in a single category. Hence, using the income category as a predictor was not deemed viable during the analysis.

Conclusion

The e-Tracker opened the possibility of tracking better the vaccination coverage, dropouts, and vaccination timeliness for EPI Bangladesh. We could use the data to demonstrate a different method of calculating the coverage and dropouts using the e-Tracker data in our study. The age-cohort-specific analysis demonstrated the deterioration of coverage estimate between pre and during the COVID era. However, the e-Tracker does not address enrolling 100% of children as it only collects a small number of covariates and does not ensure a true denominator. The true denominator can only be calculated if 100% of birth registration is done following the legal requirements (registering within 45 days of birth). Sadly, only 4.5% of births were reported within the required time frame in 2020.[28] Furthermore, the e-Tracker server only contained information on the gender of the child and their caregiver's monthly income (in the premeditated category), and their mothers' educational qualifications. It did not have any provision to gather information on the reasons for dropout or tracking if the child's family migrated from the pilot areas. Future upgradation and expansion of the program should address these issues while scaling up the system.

Contributors

Conceptualization: MS, ML, AS; Data curation: TH, AS, JH; Formal analysis: ML, AS; Funding acquisition: MS, JMA; Investigation: AS, MS; Methodology: MS, ML; Project administration: AS; Resources: AS, JH; Software: ML, JH, AS; Supervision: MS, JMA; Validation: MS, ML, AS; Visualization: ML, AS; Writing—original draft: AS; and Writing—review & editing: All authors critically revised the manuscript, and approved the decision to submit for publication.

Data sharing statement

Data may be obtained from a third party and are not publicly available. The data was obtained from the e-Tracker server hosted, operated, and managed by Extended Programme on Immunization (EPI) and Health Management Information System (HMIS), Bangladesh. The HMIS data governance does not allow us to distribute the children's data to other parties. Researchers may contact and consult to DGHS website (https://dghs.gov.bd) requesting data access.

Declaration of interests

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