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SERVICES FOR SCIENCE AND EDUCATION

Incomplete Childhood Vaccination and Associated Factors Among Children Aged 12–23 Months; Assessment of Time-To-Corrected Missed Opportunity for Vaccination for Routine Immunization: Evidence from The Cameroon Demographic and Health Survey 2018

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ABSTRACT

Background: Complete childhood vaccination remains poor in Sub-Saharan African countries. Although missed opportunity for vaccination (MOV) was found responsible for low coverage, median time-to-corrected is useful to assess delay in vaccination. We explored incomplete vaccination coverage, describe characteristics of children who experienced corrected MOV for all antigens, and estimate median survival time. Method: Secondary analyses of a sample of 1285 (total weights=1315.91) children aged 12 to 23 months with at least one vaccination date, were performed. A weighted survival Kaplan-Meier analysis was used to estimate median time-to-corrected MOV for each vaccine. Multiple correspondence analysis (MCA) was called to describe characteristics of children with corrected MOV and incomplete vaccination. We used the yellow fever vaccine (YFV) corrected-MOV status in the MCA analysis as it had the highest probability of outcome. A binary logistic regression analysis was used to identify factors associated to both outcomes. Results: Median survival time ranged from 5 (OPV0) to 96 days (Penta3). For the YFV, it was 22 days, and 65 days for MCV1. MCA analysis revealed two main dimensions characterized mainly: first, by children who experienced MOV for simultaneous vaccines, born to uneducated mothers with no occupation, who were in contact with health facility within 2 months after birth; second, by first or third bird order children, born to caregivers less than 24 years or more than 31 years, who either had an occupation skill, or were not working. Probability of corrected MOV decreased among caregivers less than 24 years as well as, in those who delivered at home and had no antenatal care. Factors associated to incomplete vaccination revealed a decrease in its odds among children whose mothers attended health facility within 2 months after birth, and mother's age more than 31 years compared to those less than 24 years old. We found an increase in the odds of incomplete vaccination among children who had less than 5 contacts with the health facility. Conclusion: Enhance effort on strategies targeting mothers during their stay in maternities, heads of households, and younger mothers, is needed to increase vaccination coverage among children. Caregivers are encouraged to pay attention to child's vaccination schedule, and complete each vaccine on time.

Keywords: incomplete vaccination, missed opportunities for vaccination, time-to-corrected event, median survival time, Demographic and Health Survey, Cameroon, immunization

INTRODUCTION

Immunization is one of the greatest public health advances in disease prevention of maternal and child morbidity and mortality. Through the Expanded Programme on Immunisation (EPI), more than 100 million infants are immunised every year, helping to avert millions of child deaths due to vaccine-preventable diseases annually [1, 2].

According to report from World Health Organization (WHO), global vaccination coverage has stagnated below the 90% target for more than a decade, meaning that a significant proportion of the global annual birth cohort remains unvaccinated. Indeed, the immunization agenda 2030 is encouraging countries to gather evidence necessary to reach this target [3].

Low coverage has been a consequence of incomplete vaccination [4-6], and low coverage has been attributed to missed opportunity for vaccination (MOV) [7]. According to the Planning guide to reduce missed opportunities for vaccination, MOV include any contact with health services by a child (or adult) who is eligible for vaccination (unvaccinated, partially vaccinated or not up-to-date and free of contraindications to vaccination), which does not result in the person receiving all the vaccine doses for which he or she is eligible [8]. Sub-definitions include corrected MOV to describe children who missed some doses while bieng eligible, and who finaly caught-up the missed vaccines [9].

In an MOV field assessment, this definition is directly observable since all children assessed are seen in the health facility and contact is traced; contraindication is directed observable by the health staff. However, when applying the definition within an available survey data set got from a DHS, it is unknow whether the child was in contraindication or not; but the solely information that is helpful to identify such indicator is the vaccination date; and one hypothesizes that if the child has been vaccinated before the survey started, it is obvious that the child had a contact with the HF and that the child was not in vaccination contraindication status.

Reasons why MOVs occur include: absence of screening of vaccination records; caregiver's attitude; health system weaknesses such as vaccine stockouts; health worker failure to screen or to assess correctly which vaccines are due; misperceptions about contra-indications to vaccines; reluctance to administer multiple vaccines simultaneously or to open a vial for only one or two children; false beliefs of upper age limits; or health facility scheduling of different days for different vaccines [10-13].

Cameroon is struggling within COVID-19 pandemic to maintain its coverage above 90%. However, according to WHO and United Nations Children's Fund (UNICEF) estimates, routine immunisation coverage remains sub-optimal (i.e., below 90%) across all routine vaccine doses in Cameroon [14]. Routine immunization schedule inlcudes BCG = Bacille Calmette Guerin, OPV at birth, DTaP-IPV-Hib-HepB = hexavalent vaccine (containing diphtheria, tetanus, pertussis, inactivated polio, Haemophilus influenzae type b and hepatitis B vaccines), HPV = human papillomavirus vaccine, OPV = oral polio vaccine, PCV = pneumococcal conjugate vaccine, RV = rotavirus vaccine 1 and second dose, measles and yellow fever at 9 months.

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Children who experienced MOV were found to receiving the said vaccines at later date, and others never returned to health facilities to be vaccinated leading to the so-called uncorrected MOV which, contribute to incomplete vaccination schedule [15]. In Cameroon evidence from the 2018 DHS found 46.5% of children aged 12 to 23 months not completely vaccinated among surveyed children [15].

MOV dose-specific has also become an important outcome to address vaccine administration quality and related [15-17]. Special attention is also paying to corrected MOV i.e., children who had chance to catch-up their vaccines before the survey started [18].

There is an increasing number of evidence on the association between complete basic childhood vaccination and associated factors in Africa, namely Cameroon [19-26]. In order to plan strategies, efforts to increase vaccination coverage should take into account factors that contribute to incomplete vaccination status of children, and identify them is a key area of focus in the life course approach and integration strategy of the Immunization Agenda 2030 [3, 27].

For an academic purpose and public health practice, the objective of this study was to identify factors that affected incomplete vaccination among 12 to 23 months children. Sub-objective includes description of children who experienced MOV for Yellow fever, and assessment of time-to-corrected MOV for all antigens.

METHODS

Dataset and Definitions

We used the 2018 Demographic and Health Survey (DHS) data where, MOV indicator variables were computed and stored in an augmented dataset [15]. Indeed, an augmented dataset is the initial survey data to which several derived variables were created and added to ease calculations of indicators. Those variables included: the number of days between the eligible status to a dose and the day the child finally received the dose; the incomplete vaccination status, and the corrected MOV status for each antigen and child. The description of the dataset was done in a previous work [15]. Overall, 46.5% of children with cards seen and dates had incomplete vaccination, and 91% experienced corrected MOV for the yellow fever vaccine [15].

Variables on the Study

Outcome Variable:

The dependent variable was the incomplete basic childhood vaccination status of children aged 12–23 months. Incomplete basic childhood vaccination achieved when the child received one but not all of BCG vaccine, three doses of pentavalent vaccines, three doses of polio vaccines, one dose of measles vaccines, and one dose of yellow fever vaccine before the age of 12 months. For median survival time, dependent variable was the corrected MOV status for each vaccine. We defined time-to-corrected MOV as the number of days beween the age at first MOV and the age at which the child was finally vaccinated, before the start of the survey.

Independent Variables:

The following explanatory variables were used in the present study: MOV status, place of residence, child's gender, caregiver's age, caregiver's education, wealth index, head of household gender, attending health facility within 2 months after birth, attending health facility in the past 12 months before the survey, bird order, occupation, regions, number of antenatal

care visits; place of delivery (government, private hospital, subdivisional medical/integrated health facility, other public sector, confessional hospital clinic, confessional health center/dispensary, medical cabinet), marital status, ceasarian mode of delivery, and marital status.

Data Management and Analysis:

A weighted Kaplan Meier curve was used to estimate the median survival time and its interquartile range before the age of 1-year for all antigens. To avoid low precision estimate of this median, estimates were obtained on the whole sample (assuming all children at risk of having a corrected MOV) in order to consider absence of corrected MOV as censored children. Indeed, in situation where censored observations are too many, unweighted Kaplan-Meier method produce biased estimations [28]. In addition, Kaplan-Meir has been used to assess immunization timeliness [29]. Here, the survival probability was estimated for a given antigen as, the sum of weights of patients who did not experience a corrected MOV without being censored (among eligible children) at that time, divided by sum of weigths of patients who were at risk of experiencing a corrected MOV just prior to that time. Here, censored children were those who received the antigen ontime.

We chose to describe characteristics of children who corrected their MOV for the YFV as it is the last vaccine received by a child before the year of one, and also because we found more than 90% of children who corrected their MOVs for this vaccine [15], and also because those who experienced this event had MOV for one or simultaneous vaccines. Those characteristics were described using a multiple component analysis. Indeed, factor analysis of multiple correspondences, also called multiple component analysis, is a statistical method of factor analysis that allows: i) to describe associations between p ($p>2$) qualitative variables simultaneously obtained on n individuals; ii) to obtain a grouping of the modalities of these variables around the dependent variable, thus giving the desired characteristics. Modalities of variables were used to characterize children who experienced corrected MOV for the YFV.

Regression analyses were weighted using sampling weight (v005), primary sampling unit (v023), and strata denoted by the rural and urban regions (v021). Although it has been claimed that, a weighted analyses in not necessary because children with card seen and dates are a subset of the survey data, and that vaccination status from recall and tick-mark are masked, performing a weighted regression enables the use of the complex sampling survey where results are infered to the population of vaccination cards, and also for having a robust regression. A weighted analysis best represents available population-based data covering all regions in the country.

Regression Principle:

Approach 1: we started by performing univariate analysis with each of the available variable. Variables with p-value less than 10% were chosen to be included in the multivariate analysis. More often, these selected variables are dependent to each other; for instance, the socio-economic status and education level. Approach 2: to avoid high multi-collinearity among independent variables, we used a multiple component analysis (MCA) to pool down all available variables, and assess their contribution to the first two components (dimensions). Secondly, a hierarchical clustering was applied to the MCA to profile children with incomplete

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immunization. The classes were characterized by individuals closest to their centre of gravity called paragons, and the variables and their modalities that best characterize the partition.

We ran two multivariate models: model 1 with all variables selected at the level of 10%; model 2: with the two main components identified and their trend assessed on the outcome using a random mixed effect model. Finally, we also use the MCA to portray the association between the modalities of the significant factors associated to incomplete vaccination found in the adjusted logistic regression. All analyses were run under the free statistical software R version 4.2.2 [30], and with the Factoshiny application.

RESULTS

Time-To-Corrected MOV for All Routine Antigens

On the whole sample of 1285 children with at least one vaccination date, median survival time for all antigens ranged from 5 to 96 days (Table 1). Median survival time of 35 days for BCG represented cut point at which 50% of children who experienced an MOV for BCG were finally vaccinated. The value reaches 92 days i.e., more than three months.

Table 1: Median survival time of all antigens among 1285 children aged 12 to 23 months Cameroon DHS, 2018

				WEIGHTED ESTIMATES		UNWEIGHTED ESTIMATES	
	Vaccine doses	Eligible children*	Corrected MOV (%)	Median survival time	IQR	Median survival time	95%Confidence limits
Birth doses	BCG	1272	91 (77.8)	35	16--92	28	28-42
	OPV0	550	4 (12.5)	5	4--5	4	4-NA
6-week doses	OPV1	1230	88 (71.54)	30	17--49	30	28-34
	PENTA1	1215	82 (63.08)	30	17--49	29	28-32
	PCV1	1143	87 (50.88)	30	16--56	30	28-35
	ROTA1	1214	114 (46.6)	30	22--56	30	28-34
10-week doses	ROTA2	1004	36 (50)	30	24--35	30.5	28-35
	PENTA2	1125	16 (53.33)	12	7--35	13.0	7-99
	PCV2	1080	15 (39.47)	19	6--35	19	6-108
	OPV2	1121	11 (29.73)	7	3--18	7	3-NA
14-week doses	OPV3	1049	20 (60.61)	31	4--91	28	4-91
	PENTA3	1057	15 (45.45)	96	4--184	90	28-184
	PCV3	1016	13 (48.15)	39	2---183	28	2-NA
9-months doses	MCV1	791	37 (44.58)	65	28---112	37	33-92
	YF	788	660 (91.9)	22	2--71	2	0-11

*Number of children who reached the recommended age of vaccine

In the same line, median time for Penta3 was estimated as 96 days (inter-quartile range (IQR) =4—184) traducing the time at which eligible children for Penta3 who missed the vaccine in previous visits, received the vaccine dose. On another words, children who reached the 14-week of life to receive Penta3, finally came back at 3 months and more to be vaccinated for

Penta3, which is very far from the recommended interval of 28 days. For the measles vaccine, vaccination after eligibility was done at a median time of 65 days, and up to 112 days.

Among those who experienced an MOV for YFV, the number of days between MOV occurrence and its corrected time ranged from 2 to 365 days (Data not tabulated here). The weighted survival median time was estimated as 22 days (IQR=2-71), which corresponded to a survival probability of 0.5.

Multivariate Exploratory Data Analysis and Data Mining for Those Who Corrected Their MOV

The previous study reported an overall MOV corrected prevalence of 18%, which varies between 12.5% (OPV0) and 91.92% for the YFV [15]. Children who corrected their MOVs were vaccinated against yellow fever between the age of 270 days and 644 days (data not tabulated here). Corrected MOV status for the YFV was mostly correlated with dimension 1 which expressed 9.7% of the variability within the dataset (Figure 1).

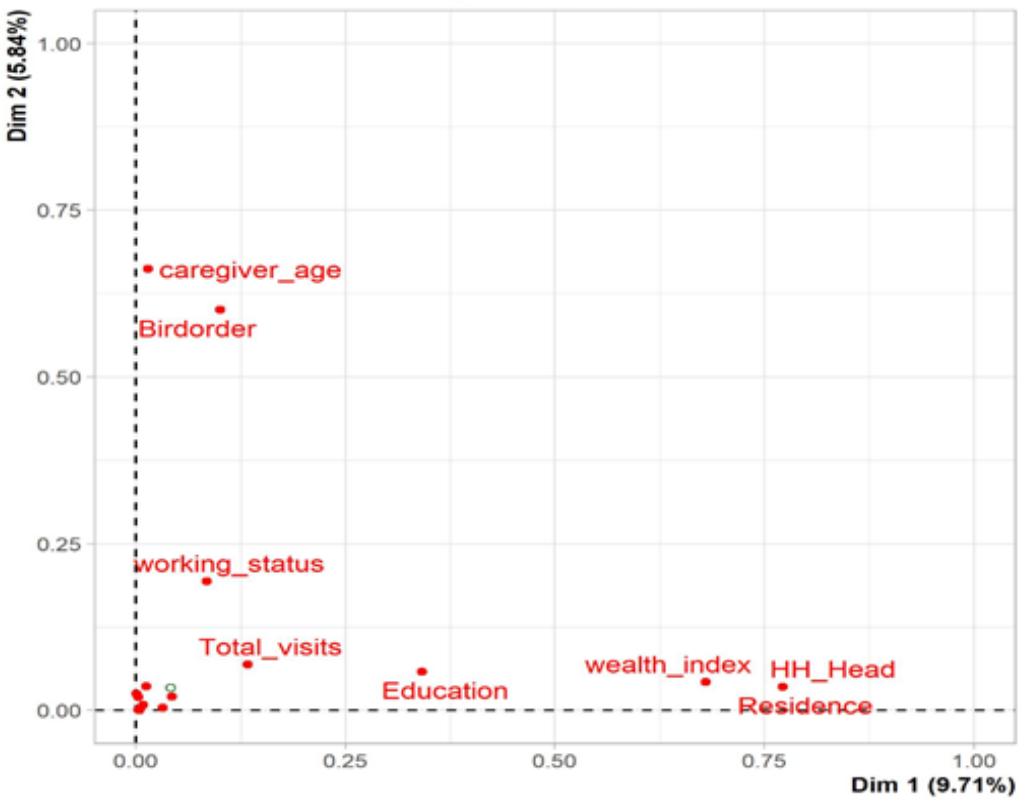

Figure 1: Description of characteristics of children 12 to 23 month who corrected their MOVs for the Yellow fever vaccine, Cameroon DHS, 2018

Dimension 1 was characterized by first or second bird order children (male or female) who experienced MOV for any vaccine, who lived in either urban or rural areas, in households were men are heads, born to uneducated caregivers who do not have an occupation (who are married or are living with a partner), and whose the overall wealth index is richer to richest; they had contact with health facility within 2 months after birth, and they experienced at least five

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contacts with the health facility i.e., they returned after missed opportunities to receive their vaccines, and they also had a contact with health facilities 12 months before the survey started (Supplementary Table 1). For the second dimension which expressed 5.84% of variability (Figure 1), it mostly represented either first child, or third and above child, born to caregivers less than 24 years old, who either had an occupation skill, or were not working at the time of survey (Supplementary Figure 1).

Multivariate Logistic Regression (for YFV corrected MOV)

The MCA analysis revealed 3 dimensions that were linked to the corrected MOV status (Supplementary Table 2). There was a significantly increase in the probability of corrected MOV for the yellow fever in dimension 1 (b-coeff=0.23831, p-value <.0001) (Supplementary Table 2). In contrary, the trend decreased with dimension 2 and 3. The probability of corrected MOV was more likely to decrease among cargeiver less than 24 years who had their first babies (b-coef=-0.272, p-value <.0001). In the same line, for the third dimension made up of delivery at home and no ANC, children were less likely to catch-up the vaccine after their first eligibility at the health facility (b-coef=- 0.3164; p-value <.0001) (Supplementary Table 2).

Prevalence of Incomplete Vaccination

From the univariate analysis (Table 2), the prevalence of incomplete vaccination was lower (42%) in children who attended health facility than those who did not (48%) and the difference was statistically significant (OR=0.71; 95%CI=0.57-0.94; p-value=0.01). This prevalence was up to 50% among female heads of households than male heads and it was significantly higher than in male children (OR=1.40; 95% CI=1.06-1.81; p-value=0.01).

In addition, prevalence of incomplete vaccination was low in mothers aged 25-31 (42.8%) than in mothers below 25 years old (50.2%) (OR=0.76; 95% CI=0.59-0.97: p-value=0.03). There was a high percentage of incomplete vaccination in children whose mothers never attended an ANC visit (53.8%) compared to those who attended at least one ANC (47.76%); however, the difference was not statistically significant (p-value>0.05).

Furthermore, households with women as heads experienced more incomplete vaccination (50) than those with males as heads (45.1%), and the difference was statistically significant (p-value=0.02).

Table 2: Factors associated to incomplete vaccination among children ages 12 to 23 months in Cameroon DHS, 2018

Variables	DHS variables and incomplete vaccination				Weighted analysis				Univariate	Weighted analysis (Model 1)			Multivariate
	ALL sample	% In the sample	Incomplete vaccination		Odds ratio (OR)	95% CI			p-value	Odds ratio (OR)	95% CI		p-value
Age cohorts			n	%									
12 to 23m	1285		592	46.07									
Child had MOV													
No	320	24.90	145	45.31									
Yes	965	75.10	447	46.32	0.99	0.77	1.26	0.92					

Health facility contact within 2 months after birth												
No	825	64.20	393	47.64	1				1			
Yes	384	29.88	161	41.93	0.72	0.57	0.91	0.01	**0.73**	**0.57**	**0.95**	**0.01**
Place of residence												
Urban	594	46.23	276	46.46	1							
Rural	691	53.77	316	45.73	0.99	0.80	1.23	0.94				
Contact within last 12 months of survey												
Yes	903	70.27	426	47.18	1.04	0.82	1.32	0.71				
No	382	29.73	166	43.46	1							
Gender of head of Household												
Male	1043	81.17	471	45.16	1				1			
Female	242	18.83	121	50.00	1.40	1.06	1.87	0.02	**1.52**	**1.11**	**2.07**	**0.01**
Child's sex												
Male	671	52.22	302	45.01	1				1			
Female	614	47.78	290	47.23	1.18	0.95	1.46	0.14	1.20	0.95	1.55	0.12
Economic status												
Richest	202	15.72	97	48.02	1							
Poorest	175	13.62	89	50.86	1.18	0.58	1.27	0.37				
Poorer	313	24.36	140	44.73	1.02	0.72	1.43	0.92				
Middle	333	25.91	143	42.94	0.80	0.57	1.14	0.22				
Richer	262	20.39	123	46.95	0.94	0.65	1.34	0.72				
Birth order												
First child	328	25.53	158	48.17	1							
Second child	261	20.31	120	45.98	0.99	0.72	1.39	0.96				
Third and above	696	54.16	314	45.11	0.94	0.73	1.22	0.63				
Caregiver's age (years)												
<=24	498	38.75	250	50.20	1				1			
25-31	460	35.80	197	42.83	0.76	0.59	0.97	0.03	0.85	0.63	1.16	0.3
> 31	327	25.45	145	44.34	0.80	0.61	1.05	0.11	**0.75**	**0.57**	**0.99**	**0.04**
Employment status												
Not working+unskilled manual + unknown	869	67.63	406	46.72	1							
Occupation	416	32.37	186	44.71	0.93	0.73	1.17	0.52				
Child covered by health insurance												
Yes	24		20									
No	1261		945									
Total eligible visits any dose												
<= 4 visits; <5	433	33.70	209	48.27	1				1			
> 4 visits; >=5	852	66.30	383	44.95	0.77	0.61	0.96	0.02	**0.70**	**0.54**	**0.91**	**0.008**
Mother's education												

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Secondary and higher	644	50.12	303	47.05	1				1			
Primary	410	31.91	192	46.83	0.99	0.77	1.27	0.94	1.03	0.77	1.36	0.85
No education	231	17.98	97	41.99	0.81	0.60	1.10	0.18	1.00	0.73	1.38	0.99
Place of delivery												
Respondent's home	287	22.33	128	44.60	1				1			
Governmental Hospital	266	20.70	123	46.24	1.26	0.90	1.76	0.17	1.30	0.88	1.91	0.19
Intergrated Health center/Dis	282	21.95	126	44.68	1.12	0.81	1.55	0.49	1.10	0.75	1.60	0.6
Other places	450	35.02	215	47.78	1.21	0.90	1.62	0.2	1.27	0.90	1.79	0.16
Number of ANC visits												
never	93	7.24	50	53.76	1.00				1			
one_two	282	21.95	120	42.55	0.77	0.48	1.25	0.29	0.69	0.31	1.18	0.17
three_more	839	65.29	393	46.84	0.83	0.54	1.29	0.41	0.74	0.45	1.23	0.25
Ceasarian mode												
No	1253	97.51	564	45.01								
Yes	60	4.67	28	46.67								
Marital status												
never in Union	176	13.70	77	43.75	1				1			
Married	708	55.10	328	46.33	0.94	0.68	1.29	0.69	0.96	0.67	1.36	0.8
Living with partner	317	24.67	144	45.43	1.00	0.69	1.43	0.97	0.89	0.60	1.32	0.56
Widowed/divorced/	84	6.54	43	51.19	1.58	0.94	2.65	0.08	1.57	0.90	2.74	0.11

Multiple Component Analysis and Hierarchical Classification in Univariate Analysis: Incomplete Vaccination

Three main components were selected regarding the scree plot (Supplementary Figure 2). The first dimension was mainly characterized by: total eligible visits less than 5, caregivers with no education, head of household status (either male of female), and secondary to higher educational caregivers. The second dimension was made up with place of delivery at home, no ANC visit.

Results of the hierarchical classification showed 3 clusters not very distinct, with sizes of 566 (44.04%), 251 (19.5%), and 468 (36.4%), respectively (Supplementary Figure 3). Link between the cluster variable and all categorical variables selected from the univariate analysis, were all statistically significant (Supplementary Table 3). Description of modalities within classes, and classes within modalities, revealed class 1 as highly dominated by children born to uneducated mothers. Indeed, class 1 is constituted of 68% of children born to uneducated mothers, and 68% of children born to those mothers are in class1 (Supplementary Table 3). For class 2, 79.8% of children were born in households, and class 2 was 100% prevalent of caregivers who never attended ANC visits. Class 3 was highly dominated by children who had at least five eligible vaccination dates for any dose (68.6%), who lived in households where women are heads (86.8%), and 84.84% of caregivers who attended secondary or higher education. Since incomplete vaccination was not correlated with none of the dimension, we went and looked at the parangons that most described the centres of the three partitions, and found that the first parangon in class 2 were, those who experienced incomplete vaccination (Supplementary Table 3).

Multivariate Logistic Regression (adjusted odds ratio-aOR for incomplete vaccination)

Overall, children who lived in households were heads are females experienced high probability of incomplete vaccination than those who lived in households were heads are males, and the association was statistically significant (aOR=1.52; 95% CI=1.11-2.07; p=0.01) (Table 2). Children who visited health facility within 2 months after birth were less likely to experience incomplete vaccination, and the result was statistically significant (aOR=0.73, 95% CI=0.57-0.94; p=0.01). In the same line, Children born to mothers aged more than 31 years were less likely to have an incomplete vaccination than very younger mothers (aOR=0.75; 95% CI=0.57-0.99, p=0.04). In addition, children who experienced more than 5 eligible visits to health facilities had less probability of having incomplete vaccination than those who had less than five visits, and the result was statistically significant (aOR=0.70; 95% CI=0.54-0.91; p=0.01); suggesting that when more opportunities are given to a child; incomplete vaccination is not expected. The risk of incomplete vaccination was lower for children whose mothers attended at least one ANC visits compared to those who never attended; however, the result was not statistically significant (aOR=0.7; CI=0.30-1.8; p>0.05) (Table 2). Furthermore, caregivers older than 31 years were less likely to experience incomplete vaccination with their children compared to those less than 24 years (aOR=0.75; CI=0.54-0.99; p-value=0.04). Education and mother's occupation were not statistically associated to incomplete vaccination.

Mixed Effect Model

For the second model (data not tabulated), we used the first two dimensions in the logistic regression to assess the trend in the odds of incomplete vaccination. We found that there was an increase in the odds with the variables in dimension 1 but, the result was not significant (beta-coefficient=0.07; p-value=0.85). For the second dimension, there was an increase in the odds of incomplete vaccination but the trend was not statistically significant (beta-coefficient=0.004, p-value=0.98).

Results' Triangulation

Based on model 1, visual representation of the component analysis highlighted two main dimensions that contribute 20.6 % and 17.52 % of the total variance, respectively. The first-dimension highlighted children who experienced less than 5 contacts for any dose, and who lived in households were either men or women are heads (Supplementary Figure 4). The second component represented children born to caregiver aged more than 31 years old, and whose children experienced contact within 2 months with the health facility (Figure 2-A and 2-B). Those results are suggesting contact after birth, role of heads of households, and respect of vaccination calendar as, main determinants of incomplete vaccination among children aged 12 to 23 months.

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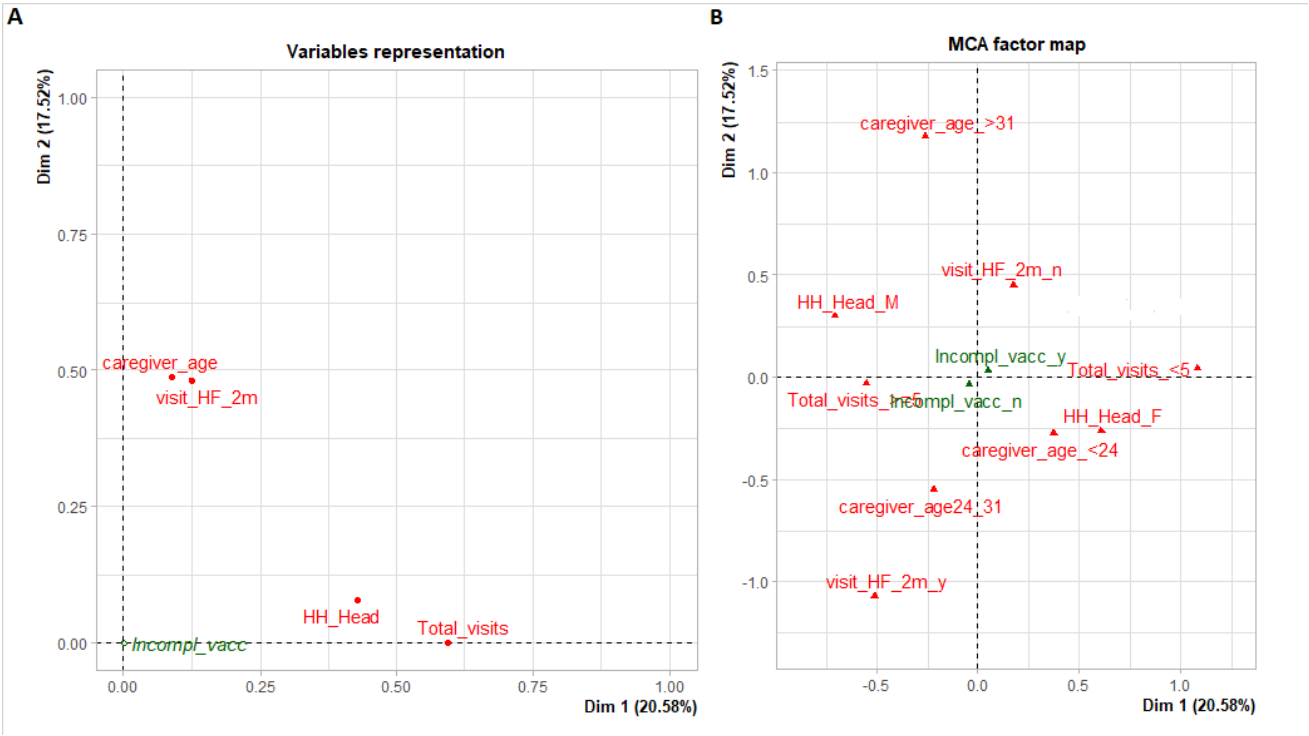

Figure 2: Multiple component analysis of Model 1-visual characteristic of children aged 12 to 23 months who experienced incomplete vaccination, Cameroon DHS, 2018

A- dimension 1 (20.6% of variability expressed): children who experienced less than 5 contacts for any dose, and who lived in households were either men or women are heads; B- second component (17.52% of variability expressed): children born to caregiver aged more than 31 years old, and whose children experienced contact within 2 months with the health facility.

DISCUSSION

The present analysis used a stratified survey sample with probability weights to assess median time to receiving missed vaccines. It also described characteristics of children who experienced such event using the yellow fever vaccine. In addition, it explored factors that contributed to incomplete vaccination four years before the ongoing coronavirus disease 19 (COVID-19) pandemics.

Median time-to-corrected MOV was found less or greater than the recommended time according to the national schedule. Indeed, the first dose of polio at birth planned within 7 days, was received the fifth day after one or more eligibilities to polio 0. Multiple doses like the pentavalent third dose, were administered more than 3 months after the first date of eligibility. Other single doses like bcg, mcv1 were administered with a long delay greater than 30 days. For instance, fifty percent of children who experienced an MOV finally caught-up the dose before or at day 65 after previous missed opportunities. Moreover, for the yellow fever vaccine where more than 90% of children corrected their MOVs, the event happened at a median time of twenty-two days. Evidence is suggesting lower education level of the mother as well as vaccination by outreach service, as independently associated with delayed completion of vaccination [31]. These observations corroborate with ours where education, including wealth index, residence, and heads of households, were found as significant characteristics of children who experienced a corrected MOV for the YFV. However, more investigation is needed to deeply

describe this outcome. As a matter of fact, delayed vaccination of children may increase the risk of infection before vaccination, compromising the success of the intervention as well as herd immunity. In terms of window of opportunity that provide best quantity of antibody, late vaccination may not give the child the expected immunity.

Incomplete vaccination among children aged 12 to 23 months, was six-points above the national prevalence in South-Africa (40.8%) [22]. It was described as more prevalent in cluster of children whose mothers gave birth at home, and who never attended an antenatal care service. One of the major concerns remains the search for factors limiting compliance with the vaccination schedule. Evidence from the multivariate analyses revealed the facility-first contact after birth as a determinant of incomplete child's vaccination calendar. Indeed, facility-first contact is attributed to Penta1 session, and has been used as time of assessing accessibility and equity in vaccination services. Indeed, 85% of children attended services in 2018 [15]. In addition, penta1 contact is also used to assess zero-dose children as recommended by WHO and GAVI [32, 33]. Hence, those observations are suggesting a complete vaccination as a positive consequence of attending week six vaccination session. Therefore, health staff need to educate mothers of new born babies before they leave health facilities, on the importance of attending the penta1 session which takes place within one month and half after birth, or two months depending of each country. In addition, contact with health facility within 2 months can also be regarded as a post-natal check (PNC) point. Indeed, it has been shown that PNC increased the odds of having complete vaccination [19]. Hence, our results corroborate with those of Ewang et al, who highlighted caregiver's utilization of health facility as one determinant of incomplete vaccination [24]. Results showed that (unweighted analysis), there was a low odd of incomplete vaccination in children whose mothers attended at least one ANC [22].

Although some studies have shown maternal occupation as one of the factors linked to incomplete vaccination [34, 35], our analysis did not point out such result. However, there is a need to study the contribution of such factor on late catch-up doses. Furthermore, results pointed out young mothers as more likely to interrupt child’s vaccination schedule than older mothers. This may be due to several factors including low understanding of vaccination schedule, the importance of respecting visits, as well as some perceptions, fears, migration of mothers, and trust of the health system [36, 37].

Another predictor of the incomplete vaccination was the gender of household head. It was shown that, children living with males as heads, experienced an increase odd of incomplete vaccination than those with women [38]. This evidence was contrary to ours. However, when we cross-tabulated the predictor with the age of mothers, stratified by incomplete vaccination status, we found that heads of household who were women, and whom children experienced incomplete vaccination, were mostly younger mothers aged less than 24 years old (data not tabulated here). Our findings therefore corrobarate with others where, maternal age [39], postnatal Care (PNC) visit [37], caregiver’s utilization of health facility [23], were significantly associated factors of complete basic childhood vaccination. In addition to that, one important factor that was assessed was the total number of vaccination contacts where a child was eligible to one or more antigens, called the total eligible visits. This factor suggested that, the probability of incomplete vaccination status decreased significantly when the number of contacts with the health centre increased. On another word, a child who completed the vaccination schedule has attended at least five contacts as recommended by the national calendar.

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Given these findings, our study recommends some policy and practice measures for addressing incomplete vaccination: health talks that emphasize on the importance of respecting child vaccination calendar by heads of household and young mothers, carefully note and attendance of week-six vaccination session for mothers of new born babies. Several studies agree with the use of appropriate communication and vaccination strategies to improve vaccination coverage [15, 24]. Others are more specific on the type of strategies to implement i.e., public health interventions targetting children born to uneducated mothers and fathers, poor families, those who have not used maternal health services, heighten health education in order to enhance full childhood vaccination [40, 41].

This work complements former studies on vaccination completeness and missed opportunities for vaccination. It uses publicly available data to perform secondary analyses. Such analyses are highly recommended by WHO to complement survey reports. It is made possible after several transformations on the initial dataset variables, including creation of several successive derived variables used to identify individuals with incomplete vaccination, MOVs, and corrected MOV. Analysis was carried on data from living children at the time of the survey, and those who had immunization records cards and vaccination dates, hence excluding information on dead children or those without immunization cards, or those whose vaccination status was made up with recall and tick-mark. These potentially have precluded a better assessment of the risk of vaccine incompleteness. The second limitation was the absence of data checking i.e., cross-checking of vaccination dates to identify inconsistencies (vaccination before birth, vaccination after the survey, vaccination series dates out-of-order or series with the same date for consecutive doses, etc.). However, during the filtering process, some of those errors are avoided, and are strongly related to the presence of children without an interview date who, did not contribute to this analysis. In addition, the calculation of ages at vaccination gave us indications of incorrect vaccination dates that are avoided during computations.

CONCLUSION

In short, public health practitioners need to pay attention to the number of days between first MOV and the receiving dose time. This indicator appears as suited to assess immunization service quality and complete child's immunity. There is much that remained to be done: identification of reasons why MOV occurs, and implementation of strategies that enable caregivers and their children to receive vaccination within the window of opportunity.

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References

1. World Health Organization. Immunization Coverage. Available online: http://www.who.int/mediacentre/factsheets/fs378/en

2. Kaslow, D.C.; Kalil, J.; Bloom, D.; Breghi, G.; Colucci, A.M.; De Gregorio, E.; Madhavan, G.; Meier, G.; Seabrook, R.; Xu, X. The role of vaccines and vaccine decision-making to achieve the goals of the Grand Convergence in public health. Vaccine 2017, 35, A10–A15. [CrossRef]

3. World Health Organization (2020) Immunization Agenda 2030 (IAI2030): A Global Strategy to Leave No One behind. http://www.immunizationagenda2030.org

4. McGee LU, Ressler KS, Boom JA, Bulsara S, Sangi-Haghpeykar H, Jibaja-Weiss ML, Montealegre JR. Incomplete Records as a Leading Cause of Missed Opportunity for Human Papillomavirus Vaccine Initiation in a Safety Net Health System. Acad Pediatr. 2021 Sep-Oct;21(7):1118-1125. doi: 10.1016/j.acap.2020.12.003. Epub 2020 Dec 21. PMID: 33359360.

5. Jani JV, De Schacht C, Jani IV, Bjune G. Risk factors for incomplete vaccination and missed opportunity for immunization in rural Mozambique. BMC Public Health. 2008 May 16; 8:161. doi: 10.1186/1471-2458-8-161. PMID: 18485194; PMCID: PMC2405792.

6. Albaugh N, Mathew J, Choudhary R, Sitaraman S, Tomar A, Bajwa IK, Dhaliwal B, Shet A. Determining the burden of missed opportunities for vaccination among children admitted in healthcare facilities in India: a cross-sectional study. BMJ Open. 2021 Mar 19;11(3): e046464. doi: 10.1136/bmjopen-2020-046464. PMID: 33741673; PMCID: PMC7986782.

7. McGee LU, Ressler KS, Boom JA, Bulsara S, Sangi-Haghpeykar H, Jibaja-Weiss ML, Montealegre JR. Incomplete Records as a Leading Cause of Missed Opportunity for Human Papillomavirus Vaccine Initiation in a Safety Net Health System. Acad Pediatr. 2021 Sep-Oct;21(7):1118-1125. doi: 10.1016/j.acap.2020.12.003. Epub 2020 Dec 21. PMID: 33359360.

8. World Health Organization (2017) Methodology for the Assessment of Missed Opportunities for Vaccination. World Health Organization, Geneva.

9. World Health Organization (WHO). WHO/UNICEF Estimates of National Immunization Coverage, Updated July 2020. https://apps.who.int/immunization_monitoring/globalsummary/timeseries/tswucoveragedtp3.html

10. WHO. Missed Opportunities for Vaccination (MOV) Strategy. Missed Opportunities for Vaccination (MOV) Strategy 2020. Available online: https://www.who.int/immunization/programmes_systems/policies_strategies/MOV/en/ (accessed on 17 April 2020).

11. World Health Organization. Leave No One Behind: Guidance for Planning and Implementing Catch-up Vaccination; Working Draft; World Health Organization: Geneva, Switzerland, 2020.

12. Mandomando, I.; Mumba, M.; Biey, J.N.-M.; Paluku, G.K.; Weldegebriel, G.; Mwenda, J.M. Implementation of the World Health Organization recommendation on the use of rotavirus vaccine without age restriction by African countries. Vaccine 2021, 39, 3111–3119. [CrossRef] [PubMed]

13. World Health Organization. Vaccine Position Papers 2020. Available online: https://www.who.int/immunization/documents/ positionpapers/en/ (accessed on 31 May 2021).

14. World Health Organization (WHO). WHO/UNICEF Estimates of National Immunization Coverage, Updated September 2022. https://apps.who.int/immunization_monitoring/globalsummary/timeseries/tswucoveragedtp3.html

15. Whegang Youdom, S., Noukeu, D.N., Nguefack-Tsague, G. and Ateudjieu, J. (2022) Missed Opportunities for Vaccination and Associated Factors among Children Aged 12 - 23 Months in Cameroon: Further Analyses of 2018 Cameroon Demographic and Health Survey. *Health*, **14**, 1081-1103. doi: 10.4236/health.2022.1410077.

16. Muluneh F, Wubetu M, Abate A. Missed Opportunity for Routine Immunization and Its Associated Factors in Gozamen District Health Centers, Northwestern Ethiopia. Glob Pediatr Health. 2020 Dec 20; 7:2333794X20981306. doi: 10.1177/2333794X20981306. PMID: 33426181; PMCID: PMC7756038.

17. Nnaji, C.A.; Wiysonge, C.S.; Adamu, A.A.; Lesosky, M.; Mahomed, H.; Ndwandwe, D. Missed Opportunities for Vaccination and Associated Factors among Children Attending Primary Health Care Facilities in Cape Town, South Africa: A Pre-Intervention Multilevel Analysis. Vaccines 2022, 10, 785. https://doi.org/10.3390/ vaccines10050785

18. Rhoda, D.A.; Prier, M.L.; Clary, C.B.; Trimner, M.K.; Velandia-Gonzalez, M.; Danovaro-Holliday, M.C.; Cutts, F.T. Using Household Surveys to Assess Missed Opportunities for Simultaneous Vaccination: Longitudinal Examples from Colombia and Nigeria. Vaccines 2021, 9, 795. https://doi.org/10.3390/ vaccines9070795

19. Tesema GA, Tessema ZT, Tamirat KS, Teshale AB. Complete basic childhood vaccination and associated factors among children aged 12-23 months in East Africa: a multilevel analysis of recent demographic and health surveys. BMC Public Health. 2020 Dec 1;20(1):1837. doi: 10.1186/s12889-020-09965-y. PMID: 33256701; PMCID: PMC7708214.

20. Adedokun, S.T.; Uthman, O.A.; Adekanmbi, V.T.; Wiysonge, C.S. Incomplete childhood immunization in Nigeria: A multilevel analysis of individual and contextual factors. BMC Public Health 2017, 17, 236. [CrossRef] [PubMed]

21. Yismaw, A.E.; Assimamaw, N.T.; Bayu, N.H.; Mekonen, S.S. Incomplete childhood vaccination and associated factors among children aged 12–23 months in Gondar city administration, Northwest, Ethiopia 2018. BMC Res. Notes 2019, 12, 241. [CrossRef] [PubMed]

22. Ndwandwe D, Nnaji CA, Mashunye T, Uthman OA, Wiysonge CS. Incomplete vaccination and associated factors among children aged 12-23 months in South Africa: an analysis of the South African demographic and health survey 2016. Hum Vaccin Immunother. 2021 Jan 2;17(1):247-254. doi: 10.1080/21645515.2020.1791509. Epub 2020 Jul 23. PMID: 32703070; PMCID: PMC7872074.

23. Kemeugni Ngandjon J, Ostermann T, Kenmoe V, Laengler A. Insights into Predictors of Vaccine Hesitancy and Promoting Factors in Childhood Immunization Programs-A Cross-Sectional Survey in Cameroon. Int J Environ Res Public Health. 2022 Feb 26;19(5):2721. doi: 10.3390/ijerph19052721. PMID: 35270416; PMCID: PMC8910338.

24. Ewang BF, Eyong ME, Cumber SN, Nkfusai CN, Yankam BM, Anye CS, Achu JR, Suh BM, Nkeng MN, Nzoyom RB, Tsoka-Gwegweni JM, Akum EA. Vaccination Coverage Under the Expanded Program on Immunization in South West Cameroon. Int J MCH AIDS. 2020;9(2):242-251. doi: 10.21106/ijma.308. Epub 2020 Jul 9. PMID: 32685280; PMCID: PMC7359757.

25. Kwedi Nolna S, Bonono CR, Nsangou Moncher M, Bindé T, Nolna D, Ongolo Zogo P. Factors influencing the performance of routine immunization in urban areas: A comparative case study of two cities in Cameroon: Douala and Yaoundé. Vaccine. 2018 Nov 26;36(49):7549-7555. doi: 10.1016/j.vaccine.2018.10.048. Epub 2018 Oct 23. PMID: 30366805.

26. Zida-Compaore, W.I.C.; Ekouevi, D.K.; Gbeasor-Komlanvi, F.A.; Sewu, E.K.; Blatome, T.; Gbadoe, A.D.; Agbere, D.A.; Atakouma, Y. Immunization coverage and factors associated with incomplete vaccination in children aged 12 to 59 months in health structures in Lome. BMC Res. Notes 2019, 12, 84. [CrossRef]

27. Lancet, T. 2021: The beginning of a new era of immunisations? Lancet 2021, 397, 1519. [CrossRef]

28. Zare A, Mahmoodi M, Mohammad K, Zeraati H, Hosseini M, Holakouie Naieni K. A comparison between Kaplan-Meier and weighted Kaplan-Meier methods of five-year survival estimation of patients with gastric cancer. Acta Med Iran. 2014;52(10):764-7. PMID: 25369011.

29. Mbengue MAS, Mboup A, Ly ID, Faye A, Camara FBN, Thiam M, et al. Vaccination coverage and immunization timeliness among children aged 12–23 months in Senegal: a Kaplan-Meier and Cox regression analysis approach. Pan Afr Med J. 2017; 27: 8. https://doi.org/10.11604/pamj.supp.2017.27.3.11534 PMID: 29296143 5.

30. R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

31. Hefele L, Syphan S, Xayavong D, Homsana A, Kleine D, Chanthavilay P, Nouanthong P, Xaydalasouk K, Phathammavong O, Billamay S, Xeuatvongsa A, Reinharz D, Black AP, Muller CP. Timeliness of immunisation with the pentavalent vaccine at different levels of the health care system in the Lao People's Democratic Republic: A cross-sectional study. PLoS One. 2020 Dec 8;15(12):e0242502. doi: 10.1371/journal.pone.0242502. PMID: 33290386; PMCID: PMC7723256.

32. GAVI (The vaccine alliance). Reaching zero-dose children. 2022. http:// www.gavi.org/our-alliance/strategy/phase-5-2021-2025/equity-goal/zero-dose-children-missed-communities.

33. Mehmood M, Setayesh H, Siddiqi DA, Siddique M, Iftikhar S, Soundardjee R, Dharma VK, Bhurgri AK, Stuckey EM, Sultan MA, Chandir S. Prevalence, geographical distribution and factors associated with pentavalent vaccine zero dose status among children in Sindh, Pakistan: analysis of data from the 2017 and 2018 birth cohorts enrolled in the provincial electronic immunisation registry. BMJ Open. 2022 May 18;12(5):e058985. doi: 10.1136/bmjopen-2021-058985. PMID: 35584879; PMCID: PMC9119190.

34. Yismaw, A.E.; Assimamaw, N.T.; Bayu, N.H.; Mekonen, S.S. Incomplete childhood vaccination and associated factors among children aged 12–23 months in Gondar city administration, Northwest, Ethiopia 2018. BMC Res. Notes 2019, 12, 241. [CrossRef] [PubMed]

35. Zida-Compaore, W.I.C.; Ekouevi, D.K.; Gbeasor-Komlanvi, F.A.; Sewu, E.K.; Blatome, T.; Gbadoe, A.D.; Agbere, D.A.; Atakouma, Y. Immunization coverage and factors associated with incomplete vaccination in children aged 12 to 59 months in health structures in Lome. BMC Res. Notes 2019, 12, 84. [CrossRef]

36. Tal Orna, Ne'eman Y, Sadia R, Shmuel R, Schejter E, Bitan M. Parents' attitudes toward children's vaccination as a marker of trust in health systems. Hum Vaccin Immunother. 2021 Nov 2;17(11):4518-4528. doi: 10.1080/21645515.2021.1971472. Epub 2021 Oct 6. PMID: 34613882; PMCID: PMC8828148.

37. Negussie A, Kassahun W, Assegid S, Hagan AK. Factors associated with incomplete childhood immunization in Arbegona district, southern Ethiopia: a case--control study. BMC Public Health. 2016 Jan 12;16 (1):27. doi: 10.1186/s12889-015-2678-1. PMID: 26757893; PMCID: PMC4711011.

38. Landoh DE, Ouro-Kavalah F, Yaya I, Kahn AL, Wasswa P, Lacle A, Nassoury DI, Gitta SN, Soura AB. Predictors of incomplete immunization coverage among one to five years old children in Togo. BMC Public Health. 2016 Sep 13;16(1):968. doi: 10.1186/s12889-016-3625-5. PMID: 27618851; PMCID: PMC5020474.

39. Fatiregun AA, Okoro AO. Maternal determinants of complete child immunization among children aged 12–23 months in a southern district of Nigeria. Vaccine. 2012;30(4):730–6.

40. Tesema GA, Tessema ZT, Tamirat KS, Teshale AB. Complete basic childhood vaccination and associated factors among children aged 12-23 months in East Africa: a multilevel analysis of recent demographic

and health surveys. BMC Public Health. 2020 Dec 1;20(1):1837. doi: 10.1186/s12889-020-09965-y. PMID: 33256701; PMCID: PMC7708214.

41. Kemeugni Ngandjon J, Ostermann T, Kenmoe V, Laengler A. Insights into Predictors of Vaccine Hesitancy and Promoting Factors in Childhood Immunization Programs-A Cross-Sectional Survey in Cameroon. Int J Environ Res Public Health. 2022 Feb 26;19(5):2721. doi: 10.3390/ijerph19052721. PMID: 35270416; PMCID: PMC8910338.