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Missed Opportunities for Vaccination and Associated Factors among Children Aged 12 - 23 Months in Cameroon: Further Analyses of 2018 Cameroon Demographic and Health Survey

Solange Whegang Youdom[1*], Diomède Njinkui Noukeu[1], Georges Nguefack-Tsague[2], Jerôme Ateudjieu[1,3]

[1]Department of Public Health, Faculty of Medicine and Pharmaceutical Sciences, University of Dschang, Dschang, Cameroon
[2]Department of Public Health, Faculty of Medicine and Biomedical Sciences, University of Yaoundé 1, Yaoundé, Cameroon
[3]Division of Health Operations Research, Ministry of Public Health, Yaoundé, Cameroon
Email: *swhegang2002@yahoo.fr

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Abstract

Background: Low vaccination coverage has been attributed to missed opportunities for vaccination (MOV). This study examines the prevalence of MOV, and its associated factors among children in Cameroon. **Methods:** Data from the 2018 Demographic and Health Survey (DHS) was analyzed for children with at least one vaccination date in the home-based record (HBR). Immunization performances such as accessibility, drop-out, and timeliness, were assessed. Service quality was assessed using MOV. Multiple logistic regression examined the effect of DHS variables on MOV outcomes, and a decision tree approach was used to study their interaction. **Results:** Overall, 1824 children aged 12 to 23 months were surveyed; 1285 (70.45%) had cards seen with vaccination dates leading to 85.03% of immunization activities. A proportion of 46.5% of children were not completely vaccinated. There was 27% of drop-out between BCG and MCV1, and less than 10% with the specific antigens. Vaccination timeliness proportions ranged from 42.18% for BGC to less than 70% for PENTA1-3. The national prevalence of MOV for simultaneous vaccines was 75.1% (95% confidence interval (CI) = 72; 79). Among those who experienced MOV, 67.4% (95% CI = 60 - 73) were uncorrected MOV. MOV was an issue in all regions and comparable in rural areas that urban areas (p = 0.2). Dose-specific MOV ranged from 2.66% (for the third dose of the pneumococcal conjugate vaccine) to 91.12 (for the yellow fever vaccine). Second birth order children experienced more MOV than first born children (ad-

justed odds ratio (aOR) = 1.67, 95% CI: 1.11 - 2.47). Children born to non-educated/primary level mothers had increased odds of experiencing a MOV than those born to educated mothers (aOR = 1.48, 95% CI = 1.007 - 2.19/aOR = 1.55, 95% CI = 1.12 - 2.09). Children from poorest households were at high risk of experiencing MOV for any vaccine than richest households (aOR = 2.04, 95% CI = 1.11 - 3.76). **Conclusion:** There is a burden of MOV and under immunized children in the population. Direct interventions that target rural poor and focus on equity gaps that relate to maternal education, socio-economic status, and family planning, should be implemented. Such strategies should aim at reducing MOV for the achievement of the immunization agenda 2030 goals.

Keywords

Missed Opportunity, Cameroon, Demographic and Health Survey, Global Health, Vaccination Date, MOV Simultaneous Vaccines

1. Introduction

Immunization has been shown to be one of the best investments a government can make to ensure the good health of the population and achieve good immunization coverage [1] [2]. Every year, it saves millions of lives from vaccine-preventable diseases [3] [4] [5]. Global immunisation coverage has stagnated at 84% - 85% for a decade, far below the Global Vaccine Action Plan (GVAP) 2020 target of 90% coverage [6] [7]. Global coverage dropped from 86% in 2019 to 83% in 2020 [3] [8] [9]. An estimated 20 million infants do not have access to vaccines or do not complete the vaccination series, the majority of whom reside in a few countries of sub-Saharan Africa, including Cameroon [3] [10].

Missed opportunities for vaccination (MOV) were identified as an important barrier hindering full immunisation coverage among eligible children [11] [12]. According to the World Health Organization (WHO), a missed opportunity for vaccination (MOV) is defined as any contact with health services by an individual (child or person of any age) who is eligible for vaccination (e.g. unvaccinated or partially vaccinated and free of contraindications to vaccination) which does not result in the person receiving one or more of the vaccines doses for which he or she is eligible [13].

Over the past five years, MOV has become a well-documented topic in different countries [14]-[20]. In African countries, several studies reported the prevalence of MOV [18]. About one in every four children under the age of two years who visited health facilities in 14 African countries missed the vaccination they were eligible to receive [17] [18]. In Cameroon, in 2011, the prevalence of MOV was found as 46.2% among 12 to 23 months children from the 2011 DHS, and half of them (23.1%) are born, from mothers with no education [15]. For several years, the coverage in penta3 is less than 80%, and that in MCV1 is also very de-

creasing [21], far below the 85% target of the country Multi-year plan (cMYP) [22].

The vaccination programme mainly targets children 0 to 11 months of age and consisted in principle of one dose at birth of BCG and oral polio vaccine (OPV), contacts at 6 and 10 weeks of life for Pentavalent (DTP-HepB-Hib), OPV, and monovalent rotavirus diarrhoea vaccine (Rotarix), an appointment at 14 weeks for Pentavalent (PENTA), OPV. From the age of 6 months, the child receives vitamin A at a semi-annual frequency, and at 9 months, the measles and rubella (RR) vaccine and the yellow fever (YF) vaccine. In addition to these antigens, the second dose of measles vaccine (introduced in 2020) is administered at 15 months to compensate for measles outbreaks [23].

The country immunization performance usually includes the accessibility/utilization of immunization services, drop-outs, vaccination timelines, cumulative coverage and subgroup coverage, reason for an absence of vaccine, and missed opportunities for vaccination. Examining these indicators is part of the recommendations from the WHO reference manual on vaccination coverage survey [24]. Although somewhat challenging to achieve specially the missed opportunities for vaccination indicators, those indicators are essentials for assessing service quality.

In 2018, when WHO published the handbook on immunization coverage surveys, very few demographic and health surveys incorporated secondary indicators into their survey reports. This is the case of Cameroon, which is one of the countries to have conducted a DHS at the same time as WHO made the manual available to the public. Further analyses have been carried on the Cameroon DHS after its publication [25] [26] [27]. However, little is found on secondary analyses including the immunization performance and quality indicators.

Increasing coverage by reducing MOV is aligned with the immunization agenda 2030 which objective is to complete each child vaccination schedule [28]. Efforts addressing the existence of MOV are a key step toward its eradication. Given that consideration, this study complements the 2018 survey report and provides further analyses of the survey data.

We set out to re-exploit the data from this survey to learn from the performance of the vaccination system before coronavirus disease 19 (COVID-19). More specifically, we were interested, in a context marked by the COVID-19 crisis, and the outbreaks of measles and cholera, and low use of vaccination services, to understand how socio-demographic variables play a role in immunization service quality, especially in the missed opportunities for vaccination.

Our aim was to provide insights from the country data set, by extracting immunization date and compute those indicators to enrich country discussion on the possibility of establishing a new cMYP, as well as other future surveys. Our first interest was to assess some immunization performance like valid coverage, accessibility, drop-out, timeliness. Secondly, the objective was to estimate the prevalence of MOV in Cameroon among people aged 12 to 23 months using the

2018 Cameroon Demographic Health Survey (CDHS) datasets, to an extend of contributing to the 2030 country immunization agenda.

2. Methods

2.1. Data

Data for this study were obtained from the 2018 Cameroon Demographic and Health Survey (CDHS). This survey was field conducted between June 16, 2018 and January 19, 2019 by the National Institute of Statistics (NIS), in collaboration with the Ministry of Public Health [28], the United States Agency for International Development (USAID), and other national and global institutions [28]. The CDHS was carried out using a two-stage cluster sampling design based on enumeration areas and household samples. The selected enumeration areas were stratified on urban and rural settings, offering an opportunity to conduct stratified analyses. The first stage involved the selection of enumeration areas with probability proportional to size. At the second stage, household sampling was done, and all children were interviewed [29].

2.2. Statistical Analysis Strategies

Children dataset was filtered to select alive children between 12 and 35 months with consistent date of birth. Because at the time of survey, the second dose of measles vaccine was not yet introduced in the country vaccination calendar, we retained data for 12 to 23 months children. Those with cards seen were chosen, and among them, children with at least one vaccination date among the following 15 antigens: BCG, OPV0, ROTA1-2, PENTA1-3, OPV1-3, PCV1-3, MCV1, and YF.

2.3. Coverage, Accessibility, Timeliness

Raw coverage (weighted/unweighted) for each antigen was estimated based among surveyed children. Drop-out rates were deduced from weights of vaccinated children, and were computed for BCG-MCV1, PENTA1-3; OPV1-OPV3; and BCG-PENTA1.

To identify the percentage of vaccination activities, and understand the path of eligible children, we calculated the ratio between the number of doses received and the total expected number, taking as a denominator the number of children with notebooks seen. In addition, we assessed the weighted proportion of children completely vaccinated, and disaggregated it by stratum, and place of residence. In the same line, we computed the zero-dose children by region: considered first as the percentage of children who did not receive PENTA1, then secondly as the percentage of children who received none of the 15 antigens. A complete schedule was defined as the percentage of children who received the basic vaccines BCG, OPV0, PENTA1-3, OPV1-3, MCV1, and YF. Accessibility to immunization service was measured as the percentage of children who received the fourth-week doses: Polio 1, Penta1, Rota1, and Pcv1.

Timeliness indicators were computed among children with cards seen and vaccination dates. Three categories of timeliness were considered: earlier, on-time, and delayed. Timeliness indicators were described using proportions and 95% confidence intervals (CIs) of doses given on time. For each category, we defined the valid interval for the dose administration by following information contained in the country calendar (see **Supplementary File** for the definition of timeliness). A median delayed age was calculated for each dose using a weighted Kaplan-Meier analysis to determine the median delayed period of vaccination.

2.4. MOV Analysis

MOV analysis was done using an edited guideline that provided very detailed steps regarding MOV implementations [30]. The subset of data used was children had cards with at least one vaccination date that is to say, at least one of the following antigens bcg, opv0, penta1-3, opv1-3, mcv1, yf. We defined MOV as: the child reached the recommended age (age-eligible) considering vaccination date, or received the dose within the window of opportunity *i.e.*, considering the minimum interval between consecutive doses in the schedule, but had not received the vaccine on card before the survey started. This later information is embedded within the DHS variable that represents sources of vaccination. The contact was defined with age at vaccination for each antigen. Several indicators were obtained from calculated age at vaccination, and especially for each antigen: the proportion of children who experienced MOV for any vaccine (corrected or uncorrected); the proportion of MOV dose-specific; the percentage of visits with MOV computed, as well as the rate or the frequency of occurrence of these MOV with respect to place of residence and strata. MOV rate was computed as the ratio of the number of vaccination dates that led to an MOV and the total number of eligible (to any vaccine) dates. Forest plots were used to portray the overall MOV indicators among strata using a random effect approach that accounts for region immunization performance, caregivers' accessibility to health care settings, and health workers performance.

We did not include vitamin A contact date in the analysis of MOV. However, we assessed the percentage of children receiving the supplementation in each region. In addition, we used the vitamin A vaccination date to assess whether corrected MOV was occurring at that time.

Since analysis was based on a subset of the whole survey, Timeliness and MOV analysis were not weighted as the analyzed data was a subset of the whole survey.

Determinants of MOV were studied using a multivariate regression logistic. Sociodemographic variables included child's gender, region, type of place of residence, number of eligible vaccinations per child, wealth index quintile, baby post-natal check within 2 months, visited health facility last 12 months, birth order, maternal education, head of household's education, mother's occupation, caregiver's age group, and place of delivery. To represent choices of variables

and their modalities on MOV status, we used a decision tree approach to enable interaction between variables, address MOV inequalities with the aim of tailoring interventions.

All analyses were carried, and the MOV analysis guideline implemented, in the free statistical software R (R Core team 2020, Vienna, Austria, version 4.0.3).

3. Results

3.1. Sample Description

Children less than five years within households were of 9733 among which 3577 were between 12 and 35 months (Figure 1). Among them, 1824 were 12 to 23 m, and 1753 were 24 to 35 months. A total of 2349 (1296 = 12 - 23 m; 1053 = 24 - 35 m) of them had vaccination records seen during interviews, leading to an overall of 71.05% (weighted = 69.7%) of card possession, and 99.1% (n = 1285) with cards and at least one vaccination date among 12 to 23 months children. This suggests an overall of 11 children who received no vaccine (Figure 1). Percentage of children with card seen was less than 60 in the Far North region and North-West (**Supplementary File 1**). Vaccination sources revealed very small numbers of children for whom vaccination status was reported either by the mother or tick-marked in the card (**Supplementary File 1**).

3.2. Socio-Demographic Characteristics of Caregivers and Their Children/Independent Variables

In the analyzed sample, children were born between August 6, 2016 and October 21, 2017, and interviewed between May 9, 2018 and September 11, 2018. Of the

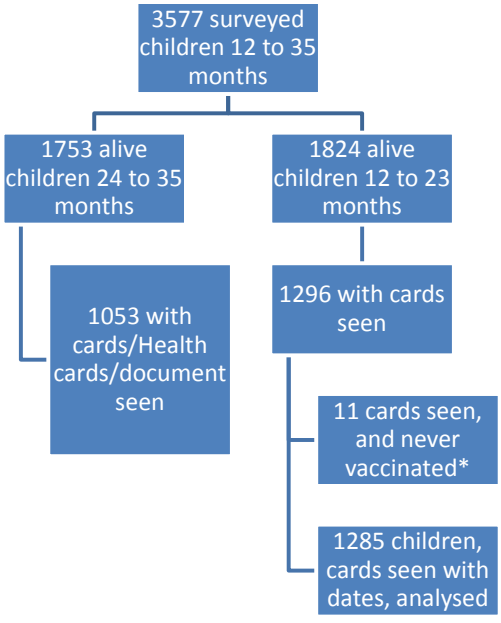

Figure 1. Flow chart of the participants' selection: Cameroon DHS, 2018. *implied children who have never received none of the following: bcg, opv0, penta1-3, rota1-2, pcv1-3, opv1-3, mcv1, yf.

1285 children aged 12 to 23 months, 52.21% were female. 53% of children lived with their mothers in rural areas. Heads of households were mostly men (81.17% male vs 18.83% female). In terms of education status, 49% of mothers were found to have none or primary education. Occupation represents 67.62% in the sample. 24.35% to 26% were households with poorer to middle wealth index status (Data not tabulated here). Around 18% of children caregivers had no education, and 50% had reached the secondary education level. They were 68.02% of children born in government hospital, and 48.48% to subdivisional medical centre/integrated centre (Data not tabulated here).

3.3. Zero-Dose Children

Of 1296 with cards seen, only 11 (0.84%) children received none of the following: bcg, opv0, penta1-3, rota1-2, pcv1-3, opv1-3, mcv1, and YF. On another hand, they were 85 (6.55%) children who have never received penta1/DTP1 on card, which was well prevalent in the East and West rural settings (**Supplementary File 1**).

3.4. Coverage and Drop-Outs

For all surveyed and alive children, unweighted and weighted raw coverage were presented in the **Supplementary File 2**. All coverages were below 80% (**Supplementary File 2**), with very low coverage attributed to YF (48.36%), and MCV1 (50%). Coverage of third dose of pentavalent vaccine varied among the 15 strata, and it was found several regions with coverage under 80% (**Supplementary File 1**). Valid coverage for Polio 0 was less than 50% and less than 85% for other antigens (**Supplementary File 2**).

Analysis of the completion of the vaccine circuit reveals 27% of general drop-out between bcg and mcv1, and 4.2% between bcg and penta1, against 8.4% of specific drop-out between penta1 and penta3, and 8.9% between polio 1 and polio 3 (**Supplementary File 2**).

Considering children with cards seen, vaccination coverage reached 80% except for YF and MCV1 for which coverage remained under 80% (**Figure 2**).

3.5. Accessibility and Equity in Vaccination Service among Surveyed Children with Cards Seen

The number of doses received by a child ranged from 0 to 15, with a mean of 12.75 (95% CI = 12.55 - 12.95). Overall, 53.47% = 693/1296 (weighted = 52.10% = 690.52/1325.38) of children 12 to 23 months were completely vaccinated with the most fundamental antigens in the country at the time of survey, suggesting 46.5% not completely vaccinated. The weighted proportion that completes the schedule was of 58.10% ((360.08/619.86)) in the urban settings and 46.83% (330.44/705.51) in the rural settings, leading to a significant difference between the two settings ($p < 0.001$). There was 85.03% of immunization activities (number of doses received divided by the number expected), suggesting that more

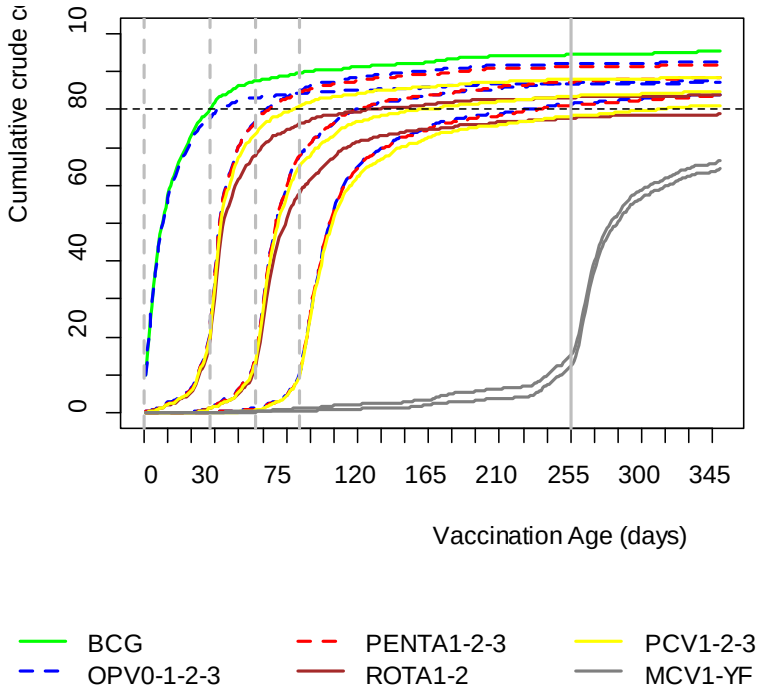

Figure 2. Cumulative coverage percentages for selected doses, by age of child, among 1296 children who showed a HBR to the interviewer, Cameroon DHS 2018. Vertical dashed lines mark scheduled vaccination ages 0, 42, 70, 98, and 270 days; denominator is the number of children 12 to 23 months with cards seen.

than 4/5 of the vaccines assessed were received by children. The percentage of those who received the fourth-week vaccines were of 79.86% overall. When disaggregating by place of residence, it was 488/598 in the urban area, and 547/698 in the rural area ($p = 0.16$). The distribution of the number of doses received by each child, disaggregated by place of residence, was portrayed in **Supplementary Figure S1**.

3.6. Timeliness

According to the data, all vaccines were administered before the recommended age. Vaccination timeliness proportions ranged from 42.18% for BGC to less than 70% for penta1-3. Indeed, less than 50% of children were receiving birth doses (bcg, opv0) within 0 and 7 days after birth (**Figure 3**), suggesting that more than 50% were receiving the dose after one week and more: 279 (21.7%) received bcg after 1 month, and only 3 children received bcg after 1 year of age (data not tabulated here). Overall, 45.5% received vitamin A supplementation at 6 months; 19 received it earlier at a median age of 163 days, and 36 after 1 year (data not tabulated here).

3.7. Missed Opportunity for Vaccination

3.7.1. Overall/Stratified Percentage of MOV

Among 1285 children with cards seen and dates eligible to one or more vaccines, we found 965 who had experienced at least one MOV for any of the antigens

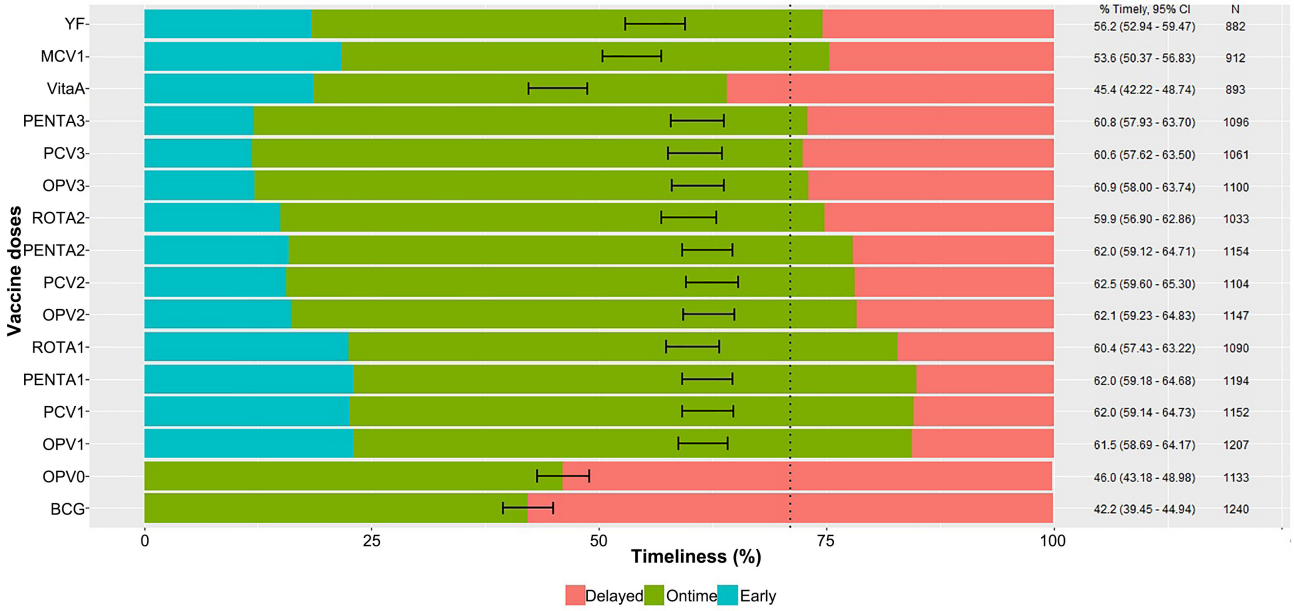

Figure 3. Vaccination timeliness among children 12 to 23 months, Cameroon DHS, 2018. Dotted line referred to the overall of card possession with dates among children aged 12 - 23 months *i.e.* 71.05%. Unweighted N: number of children with cards and dates for the vaccine dose.

under study (**Supplementary Table S3**), resulting in a proportion (unweighted) of 75.1%, 95% CI = (72.62; 77.3) versus 74.3% (977.71/1315.9)-weighted (data not tabulated).

MOV was high in the analyzed sample and exceeded 50%, within urban and rural enumeration areas (EAs) (**Supplementary Table S3**). Prevalence was comparable in rural enumeration areas (EAs) (73.22%) and urban EAs (76.2%) (p-value = 0.20). MOV percentage ranged from 60.23 in West rural to 95% in Adamaoua Urban area (**Supplementary Table S3**). Indeed, MOV prevalence ranged from 60.2% (West rural) to 84.85% (in the Littoral rural area) (ignoring Adamaoua-urban, North-West-rural, and the Southwest areas where the number of eligible children were less than 30). In the Adamaoua-rural area, they were 50 children eligible to one of more antigens, and among them, 41 (82%) experienced MOV for simultaneous vaccine. The proportion reached 84.84% in Littoral -rural area, 82.8% in the Far North rural area. In the two main towns Douala and Yaounde, MOV prevalence was 76.92% (60/78) and 76.2% (80/105), respectively. Both prevalence was comparable ($p > 0.05$).

When combining proportions using a traditional forest plot (ignoring Adamaoua-Urban and South-West), we got 75.1% (95% CI = 71; 78) of overall MOV prevalence (**Figure 4**). Of those experienced MOV, 17% had all MOVs later corrected (*i.e.*, they received the missed vaccines at a later date) (**Supplementary Table S3**).

Although there was an MOV, we assessed the proportion who never returned to the health facilities to receive one or more antigens, the so-called uncorrected MOV. Overall, among those who experienced an MOV for any vaccine, 651

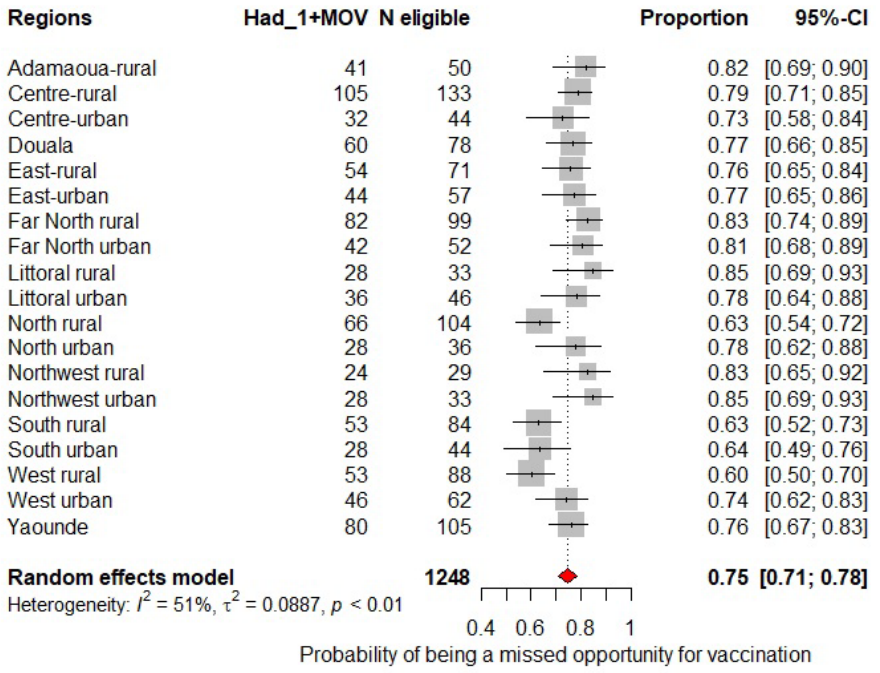

Figure 4. Prevalence of missed opportunity for simultaneous vaccines among children aged 12 to 23 months in the studied areas, Cameroon DHS, 2018. (Adamaoua-urban was removed as had less than 30 children.)

(67.46%) never received any vaccine at the time of survey (Figure 5). This proportion varied greatly among strata and reached more than 80% in some areas. For instance, in the South-rural area, 84.9% (45/53) (95% CI = 64.4; 70.3) of those who had MOV were vaccine-eligible but had never had the chance to come back to the health facility to receive their vaccines (Figure 5). In the same logic, 88.63% (39/44) never had the chance to return to the health facility in the east-urban area. Analysis also showed that of 67.46% of MOV for any vaccine, 162 (16.8%) were corrected MOV for simultaneous vaccines among which 56 (34.6%) were corrected during vitamin A contact (data not tabulated here).

3.7.2. MOV by Dose

When the analysis was done for each of the antigens, it was found that on the whole sample, the number of eligible children to a dose was greater than those who really received the dose. For instance, although 1246 were vaccinated for BCG on cards, 1272 were eligible to BCG (Table 1) at the time of survey *i.e.*, 26 more eligible children to BCG did not receive BCG at the time of survey, and this is called the uncorrected MOV among 117 (9.2%) who experienced an MOV for BCG (Table 1). In the same line, 1137 had received Polio 0, and 912 received MCV1, but only 550 and 791 were age-eligible to polio0 and MCV1, respectively. Prevalence of MOV ranged from 2.66% (pcv3) to 91.12% (yf). For instance, 10.5% of MOV for MCV1 is suggesting a reduction of coverage of 10.5%. There was only 3.12% of children who experienced MOV for the third dose of polio.

Although the MOV prevalence for YF was the highest, there was only 8.08%

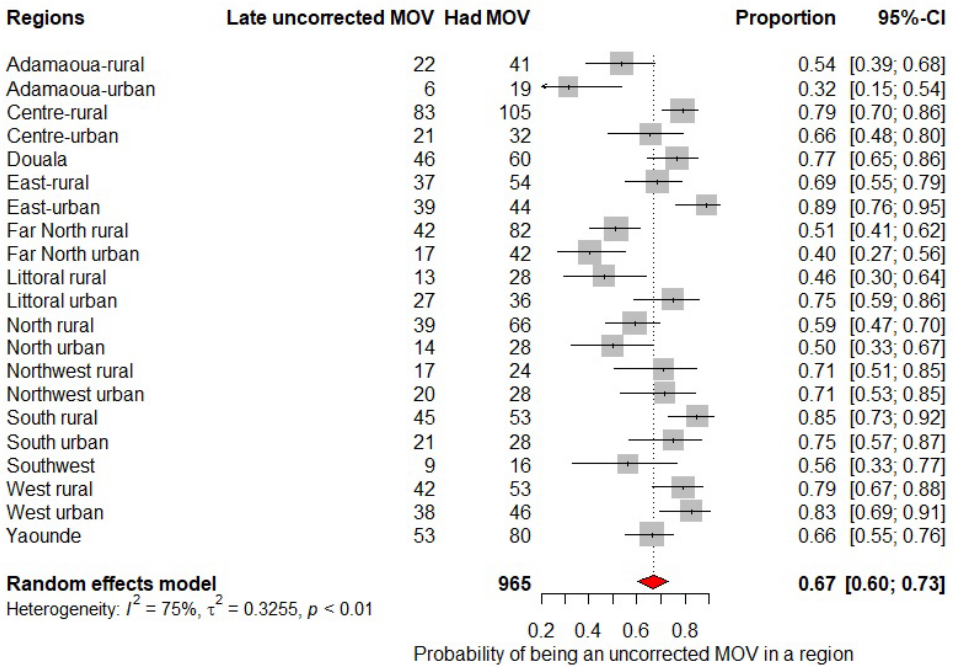

Figure 5. Prevalence of uncorrected MOV (under vaccinated) children aged 12 to 23 months in the studied areas, Cameroon DHS, 2018.

Table 1. Prevalence of dose-based missed opportunities for vaccination (MOV) among children aged 12 to 23 months, Cameroon DHS 2018.

	Vaccine doses	Eligible children*	# Had MOV	% Had MOV	# Had Uncorrected MOV	% Had Uncorrected MOV
Birth doses	BCG	1272	117	9.2	26	22.22
	OPV0	550	32	5.82	28	87.5
6-week doses	OPV1	1230	123	10	35	28.46
	PENTA1	1215	130	10.7	48	36.92
	PCV1	1143	171	14.96	84	49.12
	ROTA1	1214	245	20.18	131	53.47
10-week doses	ROTA2	1004	72	7.17	36	50
	PENTA2	1125	30	2.67	14	46.67
	PCV2	1080	38	3.52	23	60.53
	OPV2	1121	37	3.3	26	70.27
14-week doses	OPV3	1049	33	3.15	13	39.39
	PENTA3	1057	33	3.12	18	54.55
	PCV3	1016	27	2.66	14	51.85
9-months doses	MCV1	791	83	10.49	46	55.42
	YF	788	718	91.12	58	8.08

*The number is counted when the child reached the recommended age, and when the window of opportunity is fulfilled.

(58/718) who were eligible but never received the vaccine, hence suggesting that a highest proportion caught up the YF vaccine before the survey started. In contrary, highest proportions of uncorrected MOV was found for Polio1 (87.5% among those who experienced MOV), suggesting high probability of polio epidemic (Table 1). 55.4% also experienced uncorrected MOV for MCV1 among 83 children who had MOV for MCV1, which probably led to a small coverage of 47.06%, suggesting under immunized children in the population, and consequently a high determinant of measles cases and epidemic.

We found from the overall results that 67.46% (95% CI = 60 - 73) never come back to the health facility to receive any vaccine (Figure 5). When we stratified the analysis by dose, it appears that the highest proportion of this event was attributed to Polio 0 following by Polio 2 (70.27%), and Pcv2 (60.53%) (Table 1).

3.7.3. MOV Visit-Based Analysis

To learn more from the vaccination dates, we looked at the proportion of dates where children experienced MOV for each, and for any vaccine. For a given child, the total eligible visit for any dose ranged from 1 to 11, with a median of 5 visits (*i.e.*, the expected number of contacts according to the schedule), and a mean of 4.5.

Eligible vaccination dates ranged from 963 (MCV1) to 1627 (ROTA1) (Table 2). For Penta1 for instance, they were 1289 vaccination dates where children reached 42 days to receive penta1. For OPV3, they were 1110 vaccination dates

Table 2. Percentage of visits with missed opportunities for vaccination (MOV) for each dose, and for any dose (1+ doses), Cameroon DHS 2018.

Vaccine doses	Total vaccination dates*	Vaccination dates with MOV	% vaccination dates with MOV	Overall vaccination dates for any dose	# vaccination dates with MOV for any dose	% vaccination dates with MOV for any dose	Sum total mov for all doses	MOV rate
BCG	1445	205	14.19					
OPV0	1137	32	2.81					
MCV1	963	117	12.15					
YF	1000	768	76.8					
RORA1	1627	537	33.01					
ROTA2	1137	121	10.64					
PENTA1	1289	210	16.29					
PENTA2	1161	45	3.88	5795	1765	30.46	2765	0.48
PENTA3	1094	44	4.02					
OPV1	1310	187	14.27					
OPV2	1146	62	5.41					
OPV3	1110	39	3.51					
PCV1	1494	342	22.89					
PCV2	1160	56	4.83					
PCV3	1100	39	3.55					

during which children were eligible to opv3, have received opv2 and the minimum interval was 28 days. We found that the proportion of vaccination date that led to an MOV ranged from 2.81% for opv0, 33% for rota1, to 76.8% for yf (Table 2). For consecutive doses, the percentage of visits that led to MOV decreased as the number of eligible visits increased. When combining doses, of 5795 vaccination dates *i.e.*, visits where all the 1285 children were eligible to receive one or more doses, 30.4% were visits that led to an MOV.

The rate of MOV per visit across all vaccines (and all regions) was 0.477 (2063/5795, where 2063 is the total mov for any dose), suggesting that, on average, there was an MOV in every 2.1 vaccination visits among children aged 12 to 23 months (Table 2). Mean rate of MOV among children within a region and rate of MOV for each region are presented on (**Supplementary Table S3**). All regions showed a rate of MOV less than 1 (**Supplementary Table S3**) as well as each child within a region. However, the frequency of occurrence of MOV across regions varied significantly by region and ranged from 1.96 in the Adamaoua urban region to 5.88 in the South rural area (**Supplementary Table S3**), suggesting that there was an MOV every day, or almost after 1 week.

3.7.4. MOV by Dose within Regions

While a large proportion of MOV was noted for doses in general, it appears that this proportion varies greatly between doses within regions. The regions of Far North and North were those where MOV for BCG, rota1, penta1, and pcv1 was prevalent compared to others (**Supplementary Table S4**). There was also a high probability of having an MOV for YF.

3.7.5. Determinants of MOV

The first logistic regression included place of residence, mother's education, bird order, child's sex, occupation, eligible visits for any dose. In the second model, we replaced mother's education by the wealth economic index as both variables are correlated. Both models showed comparable results (Table 3). Based on the first model because of the smallest Akaike Information criterion, overall, MOV most occurred in children who experienced more vaccination contact than usual ($p < 0.0001$). MOV was significantly higher in the second birth children than first birth children (OR = 1.67, 95% CI = 1.11 - 2.47, p = 0.01). In addition, children from those who have an occupation were more likely to experience an MOV than children from parents not working or unskilled manual (OR = 1.39, 95% CI = 1.02 - 1.91, p = 0.03). As education is concerned, children born to non-educated mothers had highest probability of experiencing MOV than those born to educated mothers (OR = 1.55, 95% CI = 1.12 - 2.09). In addition, primary educated mothers had their children with a high risk of having an MOV than those educated (OR = 1.48, 95% CI = 1.007 - 2.19; p = 0.04). Children from poorest households were more likely to experience MOV than richest households (OR = 2.04, 95%CI = 1.11 - 3.76) (Table 3). The likelihood of MOV was elevated for children whose mothers did not attend either governmental (OR =

Table 3. Regression analyses with missed opportunities for vaccination (MOV) status as the dependent variable among 1285 children aged 12 to 23 months Cameroon DHS 2018.

	DHS variables and MOV				Univariate analysis				Multivariate analysis							
									First model				Second model			
Variables	ALL sample	% in the sample	MOV (any dose)		Odds ratio (OR)	95% CI		p-value	Odds ratio (OR)	95% CI		p-value	Odds ratio (OR)	95% CI		p-value
Age cohorts																
12 to 23 m	1285		965	75.1												
Health facility contact within 2 months after birth																
No	825	64.20	622	75.39	1											
Yes	384	29.88	282	73.44	0.9	0.68	1.19	0.46								
Place of residence																
Urban	594	46.23	459	77.27	1				1				1			
Rural	691	53.77	506	73.23	0.8	0.62	1.04	0.09	1.01	0.76	1.35	0.94	0.84	0.59	1.20	0.34
Contact within last 12 months of survey																
Yes	903	70.27	682	75.53	1.08	0.82	1.42	0.58								
No	382	29.73	283	74.08	1											
Sex of head of Household																
Male	1043	81.17	790	75.74	1											
Female	242	18.83	175	72.31	0.84	0.61	1.15	0.27								
Child's sex																
Male	671	52.22	490	73.03	1								1			
Female	614	47.78	475	77.36	1.26	0.98	1.63	0.07	1.23	0.94	1.61	0.13	1.2	0.91	1.57	0.19
Economic status																
Richest	202	15.72	161	79.70	1				1				1			
Poorest	175	13.62	132	75.43	0.781	0.48	1.27	0.32	0.83	0.64	1.08	0.17	2.04	1.11	3.77	0.021
Poorer	313	24.36	229	73.16	0.7	0.45	1.06	0.09	0.98	0.75	1.27	0.86	1.5	0.88	2.56	0.13
Middle	333	25.91	251	75.38	0.78	0.51	1.19	0.24	0.91	0.71	1.18	0.47	1.28	0.78	2.09	0.32
Richer	262	20.39	192	73.28	0.7	0.45	1.08	0.10	0.96	0.74	1.24	0.75	0.98	0.62	1.57	0.94
Birth order																
First child	328	25.53	232	70.73	1				1				1			
Second child	261	20.31	206	78.93	1.67	1.12	2.50	0.01	1.67	1.12	2.48	**0.01**	1.7	1.14	2.56	0.009
Third and above	696	54.16	527	75.72	1.28	0.92	1.79	0.13	1.28	0.92	1.76	0.13	1.36	0.99	1.90	0.06
Caregiver's age (years)																
≤24	498	38.75	365	73.29	1											
25 - 31	460	35.80	346	75.22	1.25	0.91	1.76	0.15								
>31	327	25.45	254	77.68	1.1	0.83	1.48	0.49								
Employment status																
Not working + unskilled manual + unknown	416	32.37	324	77.88	1				1							
Occupation	869	67.63	641	73.76	1.25	0.95	1.65	0.11	1.4	1.03	1.91	0.034	1.43	1.05	1.96	0.022

Continued

Child covered by health insurance																
Yes	24		20													
No	1261		945													
Total eligible visits any dose																
≤4 visits; <5	433	33.70	243	56.12	1				1							
>4 visits; ≥5	852	66.30	722	84.74	1.6	3.33	5.67	**<0.00001**	4.81	3.62	6.39	**<0.00001**	4.78	3.59	6.36	**<0.00001**
Mother's education																
Secondary and higher	644	50.12	482	74.84	1				1							
Primary	410	31.91	314	76.59	1.1	0.82	1.47	0.52	1.56	1.12	2.09	0.008				
No education	231	17.98	169	73.16	0.91	0.65	1.29	0.61	1.48	1.01	2.20	0.046				
Access to government hospital ANC																
Yes	260	20.23	196	75.3846	1											
NO	874	68.02	656	75.0572	1.0177	0.738	1.403	0.9								
Access to sub-divisional medical center/integrated ANC																
YES	511	39.77	385	75.3425	1											
NO	623	48.48	467	74.9599	1.0202	0.713	1.337	0.8								

1.02; 95% CI = 0.74 - 1.4), or medical/integrated centre (OR = 1.02, 95% CI = 0.71 - 1.34). However, in both cases, the results were not statistically significant (Table 3).

3.8. Classification and Regression Tree

Group 1 was made of children who experienced at least five contacts with the health centres; they represent 66% of the whole population and 85% of MOV for any vaccine (Figure 6).

Group 2 was composed of children who had less than 5 visits, who were born to mothers who had no occupation, and they represent 11% of the sample with 64% of MOV (Figure 6).

Group 3 was composed of children with less than 5 visits, born to occupied mothers who lived in poorest conditions. They represent 6% of the sample and experienced 62% of MOV for any vaccine (**Supplementary Figure S2**).

Group 4 represented second birth children born to mothers who reached secondary education and lived in rural areas. They represent 2% of the studied sample and experienced 67% of MOV for at least one antigen (Figure 6).

4. Discussion

Vaccination coverage surveys have been promoted to orientate countries multi-year plan. We used the 2018 Demographic and Health Survey to learn on immunization activities throughout the country before COVID-19 in age group 12 - 23 months. Several findings of importance were obtained for the Cameroon

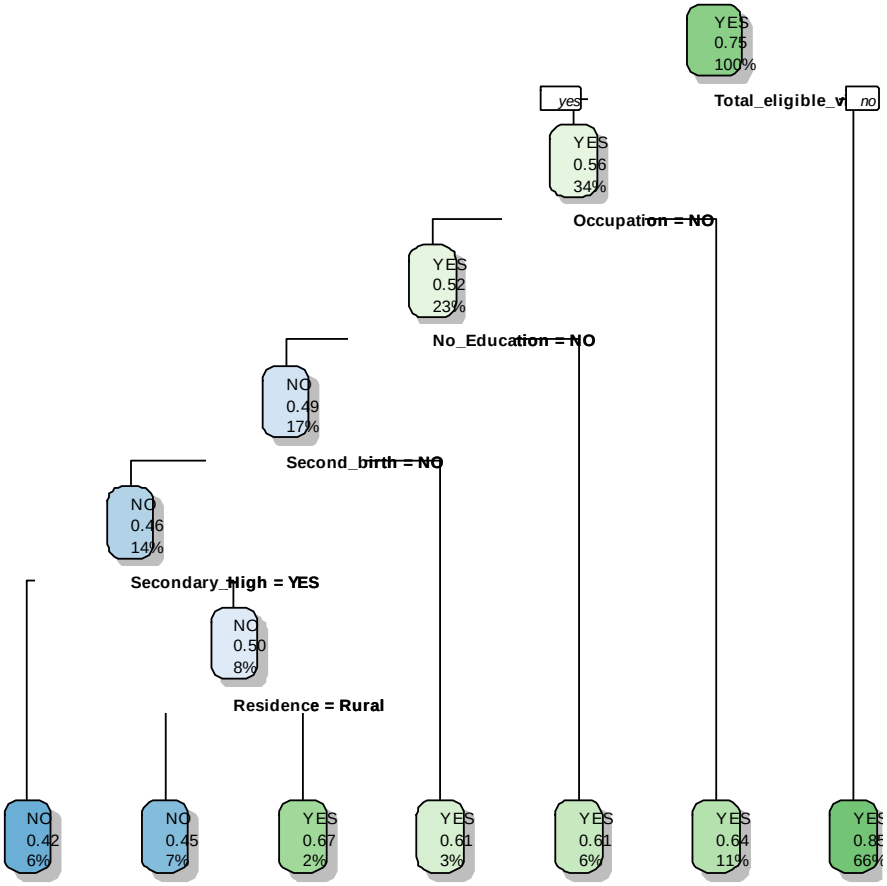

Figure 6. Classification and regression trees for missed opportunities or vaccination among 1285 children aged 12 to 23 months, Cameroon DHS, 2018.

vaccination program. It was found that four years ago, seven out of 10 surveyed children had vaccination cards, and coverage of each antigen was below 80%. Some regions persisted with very low card possession, and very low coverage for some antigens. Overall, there was more than 80% of accessibility to health services by the child during 0 and 11 months. Most vaccines were administered at late dates including measles vaccine, which was seen in the very few proportions of children receiving valid dose vaccine. Indeed, more than 50% of birth doses including polio were delayed, which probably suggests that protective immunity was insufficient, and therefore contributed to a high probability of polio outbreak.

Since 2020, the country has been experiencing recurrent outbreaks of measles, suggesting that the doses received did not confer the expected immunity, because received very late. At present, and at the time of writing this article, coverage for MCV1 is still below 80% despite efforts made by the country to achieve sustained high coverage [8]. The specific (DPT-Hi + Hb1–3) and general (BCG-Measles/Rubella) dropout rates of vaccination with evidence were 14.1 and 50.0% respectively [21]. In this study, general (BCG-Measles/Rubella) dropout rates were 27.25%, suggesting an increase compared to recent studies.

Among eligible children, three out of four children experienced an MOV for simultaneous vaccines in all levels of the sociodemographic variables. The proportion of MOV had significantly increased since 2011 (46.2%), observation made from a study that assessed MOV in Sub-Saharan African countries [15]. In addition, our result is like some other studies in Africa where it was found that among children aged 0 to 23 months, 76% had a missed vaccination [19]; 51% (99/195) in Chad 66% (149/225) in Malawi had one or more MOV among eligible children < 24 months in the survey [31]. In Nigeria, it was found between 32.8% and 53% (1005/1912 children 12 to 23 months) [20] [32]. In South Africa, the national prevalence of MOV among children aged 12 - 23 months was lower than in the present study *i.e.*, 40.1% [33]; but was comparable to the Ethiopian prevalence (74.9%) [34]. Such heterogeneity in these estimates is strongly related to each country's vaccination schedule and the type of study design implemented.

Very few studies on MOVs have evaluated the percentage for each antigen vaccine [32] [33] [34]. This study has the merit of having contributed to such an evaluation. The percentage of MOV was very high for the yellow fever vaccine and was less than 20% for other antigens. The current MOV prevalence study was lower than the study conducted in less than 24 months children [34]. In Ethiopia, major vaccines with high missed opportunity were OPV0 (67.8), BCG (17.3%), and Measles (14%) [34].

It should be noted that among children who experienced MOV for YF, we have noted a large percentage of children who caught up with the said vaccine, but received it at late dates. When we removed YF from the analysis, the overall percentage of MOV was estimated as 37.7% (data not tabulated).

The data told us that some children who were age-eligible when they were in contact with the health facilities, never had the chance to be vaccinated. Indeed, almost seven out of 10 children (67%) did not catch-up one or more doses although being eligible at the health facility, and only 16.8% received the missed vaccines later and before the survey started. Of the MOV for the yellow fever vaccine, a significant proportion was not caught up, demonstrating the presence of under vaccinated children, and consequently, a gateway to yellow fever epidemics. Indeed, according to a WHO report, the yellow fever epidemic had affected the country's districts in 2021 [35]. These observations suggest ongoing continuity in the surveillance, preparedness, and response system.

Despite strategies put in place to increase coverage [36], the fact that there is a persisting number of children who are not receiving all the vaccines is a good indicator to assess the quality of vaccination services and may implying the contributions of parents, health staff and community health workers in the completion of children immunization status. This study did not assess the determinant of such outcome but we belief that, in a context where vaccination services are disrupted by the ongoing coronavirus 2019, there is an urgent need to adapt a general framework at primary care settings to enable children to catch-up their

vaccines.

Identifying determinants of MOV is useful to designing, implementing, and evaluating complex-appropriate quality improvement interventions or addressing missed opportunities. Our study found a significant increased risk of MOV among children born to uneducated mothers, as well to those who reached the primary education level. In addition, subgroup analysis of MOV revealed different interaction patterns made up of number of contacts with health facility, education level, wealth index, and residence place. This finding matches with previous studies that found children whose mothers were educated, associated to a range of positive outcomes such as child immunisation [37]. The fact that children born to less educated mothers experienced a high risk of MOV, raises the question of mothers' knowledge of the EPI, as well as the attitude of health workers towards these mothers. Such recommendation has been identified in another study where it was found that mothers were having a negative attitude towards immunization [38].

In addition, it was shown that there is a high risk of MOV when the number of vaccination dates exceeded the recommended number. Indeed, in normal circumstances, the schedule provides for five contacts before the age 12 months. When it appears to increase, it suggests the non-respect of the national calendar, and therefore calling for all parties to get involved in preventing vaccine stock-outs, poor communication among stakeholders (including insufficient advocacy and inadequate social mobilisation), and good collaboration between the public and private health sectors [39].

Our data further show differential odds of missed opportunities for vaccination across the twelve regions in the country. There may be a wide variation across the regions in the logistics of ensuring access to vaccination services and, perhaps, the behavioural and social drivers of vaccination. Thus, it is essential to conduct appropriately designed research to understand the reasons for the high burden of missed opportunities for vaccination, as well as more general reasons why a high proportion of children who are facility-contact-eligible, are not vaccinated in Cameroon.

As soon as under vaccinated children are identified and vaccinated, the question of immunity relative to antigens remains to be questioned, because the doses received late will not confer the same immunity as those received on time, or even this immunity will not exist, which will lead to the resurgence of epidemics. It is therefore urgent to focus on adhering to the vaccination schedule during vaccination sessions, and to encourage mothers whose children have experienced MOV, the use of other health centres, to have their children vaccinated before the age of 5 years. Such efforts are essential for building health system resilience and maintaining immunization programme capacity to optimally deliver essential health service in a context where covid-19 has disrupted immunization services.

In addition, we would recommend some bold areas of action through which

MOV can get reduced: supervision of health workers and make sure they deliver key messages; improve investment in monitoring of programme activities (lack of follow-up activities); improve investment in annual health and education of beneficiaries, reduce stock-outs, always screen vaccination record for any child attending the health facility either for a medical consultation or other, make use of promotional materials to deliver key messages to non-educated mothers. Some other promising areas include the implementation of a series of interventions aimed at improving community knowledge and practices, raising health workers' awareness, and fostering the integration of immunization with other health services [16] [19] [40].

This study has used a stratified survey design to portray the vaccination quality in Cameroon. The launch of the Immunisation Agenda 2030 (IA2030) marks the beginning of a new era for accelerating immunisation progress globally, with a key objective of leaving no child behind or ensure that not leave any child under vaccinated behind [28]. Our contribution to such objective is reflected in the findings tabulated from documented evidence only, saying that recall, and tick -mark statuses were used as denominators. Results are quite important first to document the burden of MOV, secondly to orientate vaccination strategies, by combining several socio-demographic factors.

5. Limits

Some limits were identified: misclassification biases of children in their age group due to missing interview dates. Ages at vaccination were negative for certain antigens leading to possible information bias on the said date. These biases were circumvented when defining MOVs. It is true that MOVs as defined by the WHO, require to know if the child has a contraindication to vaccination. This includes fever or any clinical condition that may lead to the absence of vaccination. The survey dataset did not present such information. However, since this is an investigation that has been conducted in households, and for which vaccination records with dates provided the vaccination status for each antigen, it is therefore obvious that the child did not have such a condition at the time he was vaccinated. For children who had never had the opportunity to correct their MOVs, the reasons for non-vaccination were not available to support a hypothesis of contraindicated vaccination. Nevertheless, it is possible to document these reasons by means of qualitative surveys.

6. Conclusion

The merit of this work is to have grasped the advantage of a stratified survey to highlight the performance of the vaccination system in Cameroon and identify some determinants that hinder child's immunization. MOV needs to be addressed in all districts, and promising areas could be implementation research strategies. Secondary analyses should always be integrated in country DHS survey analyses.

Declarations

Ethics Approval and Consent to Participate

This study was based on a secondary dataset with no identified information on the participant. The authors obtained and were granted approval to use the dataset DHS program.

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Authors' Contribution

SWY conceived the analysis plan, analyzed the survey data, and wrote the manuscript draft; DNK, and GNT contributed in the writing and the critical review of the manuscript; under close supervision of AJ. All authors read and approved the final version.

Conflicts of Interest

No potential conflicts of interest were disclosed.

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Availability of Supplementary Data

Supplementary files (Tables and Figures) are available at http://www.docs.google.com/spreadsheets/d/1Hmnd9Iq0-UJ-5uj6XPml5UmQn4YUgBH2/edit#gid = 674011018