Vaccine: X 12 (2022) 100244

Contents lists available at ScienceDirect

Vaccine: X

journal homepage: www.elsevier.com/locate/jvacx

Community-based survey to assess seroprevalence of poliovirus antibodies in far-north Cameroon in 2020

Marie Claire Endegue [a], Carolyn Sein [b], Rocio Lopez Cavestany [b], Visalakshi Jeyaseelan [b,*], Tess Palmer [c], Gnakub Norbert Soke [c], Aissata Diaha [c], Basit Jafri [d], Bernardo A. Mainou [d], Harish Verma [b], Ondrej Mach [b]

[a] Polio Laboratory, Centre Pasteur de Cameroon, B.P. 1274 Yaounde, Cameroon
[b] Polio Eradication, World Health Organization HQ, 1211 Geneva, Switzerland
[c] Global Immunization Division, Centers for Disease Control and Prevention, Atlanta, GA 30333, USA
[d] Population Immunity Laboratory, Polio and Picornavirus Branch, Centers for Disease Control and Prevention, Atlanta, GA 30333, USA

ARTICLE INFO

Article history:
Received 28 October 2022
Received in revised form 28 November 2022
Accepted 1 December 2022
Available online 5 December 2022

Keywords:
Poliomyelitis
Seroprevalence survey
Oral poliovirus vaccine
Vaccination campaigns
Routine immunization
Far North Region Cameroon

ABSTRACT

Background: This study assessed seroprevalence of poliovirus antibodies in children from selected poliovirus high-risk areas of the Far North region of Cameroon which serves to monitor polio immunization program.
Methods: This was a community-based cross-sectional seroprevalence survey involving collection of dried blood specimens (DBS) among children aged 12–59 months (n = 401). Multi-stage cluster sampling using GIS was applied to select the study sample. Collected DBS were analysed with microneutralization assays for poliovirus neutralizing antibody levels.
Results: The overall seroprevalence of types 1, 2 and 3 neutralizing antibodies were 86.8 % (95 % confidence interval [CI]: 83.1–89.8), 74.6 % (95 % CI: 70.1–78.6) and 79.3 % (95 % CI: 75.1–83.0), respectively. Median titers (log_2 scale) for type 1, 2 and 3 were 7.17 (6.5–7.5), 5.17 (4.83–5.5), and 6.17 (5.5–6.5), respectively. There was an increasing trend in median titers and seroprevalence with age, statistically significant between the youngest and oldest age groups ($p < 0.001$).
Conclusion: Though there were several opportunities for vaccination through supplementary immunization activities (SIA) and routine immunization (RI), seroprevalence levels were low for all three serotypes, particularly for type 2. This highlights the need to strengthen RI and SIA quality coverage. Low population immunity makes Cameroon vulnerable to new importations and spread of polioviruses.

1. Introduction

Poliomyelitis, a vaccine-preventable disease caused by polioviruses, is targeted for global eradication. Wild poliovirus (WPV) strains of serotypes 2 and 3 were certified eradicated globally in 2015 and 2019, respectively.[1,2] Since the certification of WPV eradication of all three types in Africa in August 2020, Afghanistan and Pakistan are the two remaining endemic countries. However, there has been a persistent circulation of vaccine-derived poliovirus (VDPV).[3] VDPV type 2 predominates, largely seeded from the use of trivalent oral poliovirus vaccine (tOPV) before the 2016 switch and from the use of monovalent OPV (mOPV) to control circulation of VDPVs in countries with low vaccine immunization coverage.[4,5] Globally in 2021, there were six paralytic cases of WPV1, and 672 cases were due to circulating VDPV type 2 (cVDPV2).[6,7] The primary sites of cVDPV2 transmission occur in western Africa, with Nigeria as the epicenter. From 2015 to 2019, no cVDPV2 cases was reported in Cameroon, but rather, seven cases in 2020 and three cases in 2021. These cases were genetically linked to outbreaks in neighboring Chad and Central African Republic[7].

Cameroon has a fragile security profile and a weak health care system, due to a number of factors, including the terrorist and militant activities of the Islamic group Boko Haram (crossing from Nigeria to the northern part of Cameroon) and socio-political unrest [8]. This has resulted in massive displacement of populations and a significant deterioration of national infrastructures, hampering optimum healthcare services and immunization coverage in these areas.[8,9].

Risk of importation of polioviruses is considerable due to the refugee influx, especially from Nigeria and Central Africa (~443,000 in 2020)[9]. Since 2018, internally displaced persons

* Corresponding author at: Polio Department, World Health Organization, Avenue Appia 20, CH-1211 Genève 27, Switzerland.
E-mail address: jeyaseelanv@who.int (V. Jeyaseelan).

https://doi.org/10.1016/j.jvacx.2022.100244
2590-1362/

(IDPs) have increased from 700,000 to > 1 million at the end of 2020[9]. Displacements were also caused by intense flooding in the Far North, which in turn affects the population's nutrition status. Overall insecurity, poor infrastructures, difficult terrain, and population movements resulted in underperforming routine immunization (RI) and supplementary immunization activity (SIA) systems in Cameroon, leading to an increased risk of spread of polio outbreaks.

Since the introduction of injectable poliovirus vaccine (IPV) into RI in 2015, joint WHO/UNICEF estimates report 22 %, 70 %, 65 %, 67 %, 67 %, and 70 % coverage levels each year between 2015 until 2020.[10] Notably, results from a 2018 DHS health survey report considerable variability in RI coverage between regions[11]. For poliovirus immunization, Cameroon heavily relies on supplementary immunization activities (SIAs) to vaccinate the population. From 2016 to 2020, there were a total of 29 mass vaccination campaigns with different oral poliovirus vaccines to prevent and mitigate spread of poliovirus outbreaks due to importation from Nigeria. Vaccination through RI is documented via vaccination cards; however, no records at the individual level are made during SIAs.

The aim of this study was to assess the seroprevalence of poliovirus neutralizing antibodies in children in selected poliovirus high-risk areas of the Far North region of Cameroon. This is useful to inform future programmatic strategies for poliovirus elimination efforts in the country and identify risk factors associated with low seroprevalence. Hence the primary objective of the study was to assess seroprevalence for poliovirus of all three serotypes in children aged 12–59 months, living in high-risk areas, in the Far North region. Secondary objectives include the influence of demographic factors and vaccination history on polio seroprevalence. Assessing the population seroprevalence for type 2 poliovirus is especially relevant due to the repeated cVDPV2 outbreaks in neighboring countries and persistent risk of importation.

2. Methods

This was a community-based cross-sectional serological survey involving collection of dried blood specimens (DBS) to assess seroprevalence of poliovirus neutralizing antibodies among children living in areas considered at high risk for emergence and spread of poliovirus outbreaks in Cameroon. Eight districts from the Extreme-North region were selected: Goulfey, Kousseri, Koza, Mada, Mokolo, Makary, Mogode, and Mora. These districts were targeted because they have a high number of populations considered as high risk for poliovirus transmission, including nomads, refugees and IDPs. The study period was between January and December 2020.

The study sample was selected using a multi-stage cluster sampling method. Due to high mobility in these areas and limited country resources, settlement location points were obtained through existing GIS databases (i.e., Lake Chad Basin initiative). Through random sampling from all districts, 59 settlements were selected using a random number generator. Settlement location points were compared to current high-resolution satellite imagery to validate that these were not abandoned settlements. Viable identified structures were then randomly selected for the purposes of this study. If the chosen structure was a single household and had eligible children (i.e., age 12–59 months), the surveyors randomly selected one child and conducted the data-collection survey. If a household was empty, a nearest household was chosen and child in the age criteria was included for the survey. Inclusion criteria were children in the target age group (12–59 months), living in the selected 9 districts of the Far North region during the time of the survey, and parent/legal guardian consent for participation. Exclusion criteria included children with any suspicion of blood clotting disorder, contraindication for venipuncture, and hospitalization.

Sample size calculation were done using PASS software v.14.[12] With an assumed type 1 seroprevalence of 80 %, a 95 % confidence interval with a 16 % width (intraclass correlation coefficient [ICC] = 0.167), a sample size of 188 children was obtained. Using the WHO recommended ICC of 0.167, selecting 6 children per cluster, we could achieve a sample of 474 (rounded to 500) children with 58 clusters (design effect 1.833) after adjusting for an attrition of around 20 % (due to low-quality dried blood specimens, non-responsive households, or refusals). It was estimated that 15–18 structures would need to be selected by GIS to enrol about 6 eligible children in each cluster.

Survey teams collected data on key indicators related to socioeconomic status such as education level of mother and immunization history. Vaccination history for OPV and IPV receipt through RI was assessed from vaccination cards (when available). The number of OPV or IPV doses received through campaigns was always obtained by parental recall as no documentation exists. Then, a trained phlebotomist collected dried blood specimens (DBS) (up to 80 μg of blood). Centre Pasteur of Cameroon shipped samples to the Centers for Disease Control and Prevention in Atlanta where micro-neutralization assays were performed to assess levels of poliovirus antibodies against all poliovirus types (Reference PMID 26983734). Seropositivity was defined as reciprocal titres of poliovirus neutralizing antibodies ≥ 8 (≥ 3 in $\log_2$ scale).

This study received approval from the Ethical Review Committee of the World Health Organization and from Cameroon's Ministry of Public Health and National Ethics Committee.

3. Results

3.1. Socio-demographic characteristics of the study sample:

There were 804 structures screened of which 777 (96.6 %) were selected and visited. Of those selected structures with household, 401 (52.0 %) children were eligible and included in the study. Socio-demographic and geographical distribution characteristics of the sample are presented in Tables 1a and 1b.

3.2. Vaccination history:

Only 36/401 (9.0 %) parents presented with their child's vaccination cards during enrolment. Among those who presented with vaccination cards, 100 % (36/36) had received ≥ 3 doses of bOPV while 94.4 % received IPV in routine immunization at 14 weeks of age. Parental recall revealed that 53.9 % of children had received ≥ 3 OPV doses through SIAs.

3.3. Seroprevalence:

The seroprevalence of poliovirus neutralizing antibodies serotypes 1, 2 and 3 across all age groups was 86.8 % (95 % CI: 83.1–89.8), 74.6 % (95 % CI: 70.1–78.6) and 79.3 % (95 % CI: 75.1–83.0), respectively (Fig. 1). There was an increasing trend of seroprevalence of all three types as age increased, although statistically significant difference was found only between the youngest age group children (12–23 months) and children above $\geq$ 48 months. Children > 55 months were born before the switch from tOPV to bOPV that occurred in April 2016. There was no statistically significant difference in type 1, 2 and 3 seroprevalence between ages 48–55 and > 55 months (P = 0.350; P = 0.358; P = 0.739, respectively for serotypes 1, 2, and 3 serotypes).

Table 1a
Socio-demographic distribution by age groups.

Demographic variables	Age of the child				Total (N = 401)
	12–23 months (N = 57)	24–35 months (N = 111)	36–47 months (N = 113)	48–59 months (N = 120)	
	% (n)	**% (n)**	**% (n)**	**% (n)**	**% (n)**
District					
Goulfey	19.3 (11)	18.0 (20)	15.0 (17)	11.7 (14)	15.5 (62)
Kousseri	3.5 (2)	14.4 (16)	8.8 (10)	14.2 (17)	11.2 (45)
Koza	24.6 (14)	15.3 (17)	15.0 (17)	15.8 (19)	16.7 (67)
Mada	10.5 (6)	9.9 (11)	11.5 (13)	9.2 (11)	10.2 (41)
Makary	26.3 (15)	17.1 (19)	17.7 (20)	20.0 (24)	19.5 (78)
Mogode	7.0 (4)	21.6 (24)	23.9 (27)	16.7 (20)	18.7 (75)
Mokolo	7.0 (4)	3.6 (4)	0.9 (1)	8.3 (10)	4.7 (19)
Mora	1.8 (1)	0.0 (0)	7.1 (8)	4.2 (5)	3.5 (14)
Sample population					
Residents	94.7 (54)	94.6 (105)	96.5 (109)	92.5 (111)	94.5 (379)
Refugees	3.5 (2)	0.0 (0)	0.0 (0)	3.3 (4)	1.5 (6)
Internally displaced	1.8 (1)	2.7 (3)	0.9 (1)	2.5 (3)	2.0 (8)
Nomads	0.0 (0)	2.7 (3)	2.7 (3)	1.7 (2)	2.0 (8)
Type of toilet					
Individual toilet	36.8 (21)	29.7 (33)	32.7 (37)	31.7 (38)	32.2 (129)
Common toilet	50.9 (29)	50.5 (56)	55.8 (63)	47.5 (57)	51.1 (205)
Open fields defecation	12.3 (7)	19.8 (22)	11.5 (13)	20.8 (25)	16.7 (67)
Religion					
Muslim	59.6 (34)	58.6 (65)	55.8 (63)	57.5 (69)	57.6 (231)
Christian	26.3 (15)	29.7 (33)	29.2 (33)	29.2 (35)	28.9 (116)
Animist	12.3 (7)	10.8 (12)	14.2 (16)	12.5 (15)	12.5 (50)
Other	1.8 (1)	0.9 (1)	0.9 (1)	0.8 (1)	1.0 (4)
Education of parent					
Primary	10.5 (6)	27.0 (30)	24.8 (28)	20.8 (25)	22.2 (89)
Secondary	10.5 (6)	7.2 (8)	10.6 (12)	7.5 (9)	8.7 (35)
Kuranic school	26.3 (15)	27.0 (30)	23.9 (27)	30.0 (36)	26.9 (108)
Not educated	52.6 (30)	38.7 (43)	40.7 (46)	41.7 (50)	42.1 (169)

Table 1b
Vaccination history by age groups.

Vaccination history	Age of the child				Total (N = 401)
	12–23 months (N = 57)	24–35 months (N = 111)	36–47 months (N = 113)	48–59 months (N = 120)	
	% (n)	**% (n)**	**% (n)**	**% (n)**	**% (n)**
Vaccination card					
Available	22.8 (13)	9.9 (11)	8.0 (9)	2.5 (3)	9.0 (36)
IPV in RI [a]					
Administered	84.6 (11)	100.0 (11)	100.0 (9)	100.0 (3)	94.4 (34)
Birth OPV dose[a]	100.0 (13)	100.0 (11)	100.0 (9)	100.0 (3)	100.0 (36)
≥3 OPV doses in RI[a]	100.0 (13)	100.0 (11)	100.0 (9)	100.0 (3)	100.0 (36)
Doses of OPV in SIA[b]					
1	3.6 (2)	0.9 (1)	0.0 (0)	0.0 (0)	0.8 (3)
2	50.0 (28)	40.9 (45)	49.1 (55)	43.7 (52)	45.3 (180)
≥3	46.4 (26)	58.2 (64)	50.9 (57)	56.3 (67)	53.9 (214)

[a] Among those who presented with vaccination card.
[b] From parental recall.

The median titers by age groups are presented in Fig. 2 and Table 2 in $\log_2$ scale. Type 1 and 3 titers were high and consistent throughout all age groups (median 6.94 and 5.94, respectively). The type 2 median titers in 12–23-month age group was 4.2 (95 %CI: <3–7.5) and gradually increased with age reaching 5.8 (95 %CI: 5.5–6.8) in the 48–59-month age group ($p < 0.001$).

3.4. Risk factor associations:

Bivariate analyses reveal some socio-demographic characteristics were associated with type 2 seronegativity. Younger children and toilet users (whether at household or community level) had a significantly higher chance of seronegativity than older children ($p = 0.001$) and those who defecated in open areas ($p = 0.002$), respectively (Table 3A). There was no other socio-demographic factor that was associated with type 1 or type 3 seronegativity except for age (Table 3B). Education level of the mother showed a 10 % level of significance and hence was considered into multivariable analysis model.

Multi-variable analyses (Table 4) for type 2 immunity demonstrated that children between 12 and 23 months had 2.2 (1.4–3.5) odds of remaining seronegative as compared to children above 23 months while children who used common or individual toilet had nearly 4 (1.7–9.1) times odds of remaining seronegative as compared to children who defecated out in open areas.

4. Discussion

The overall polio antibody seroprevalence against all three poliovirus types was low (<90 %), despite multiple rounds of OPV campaigns between 2016 and 2020 in the far north region for Cameroon. Seropositivity was the lowest for the youngest age

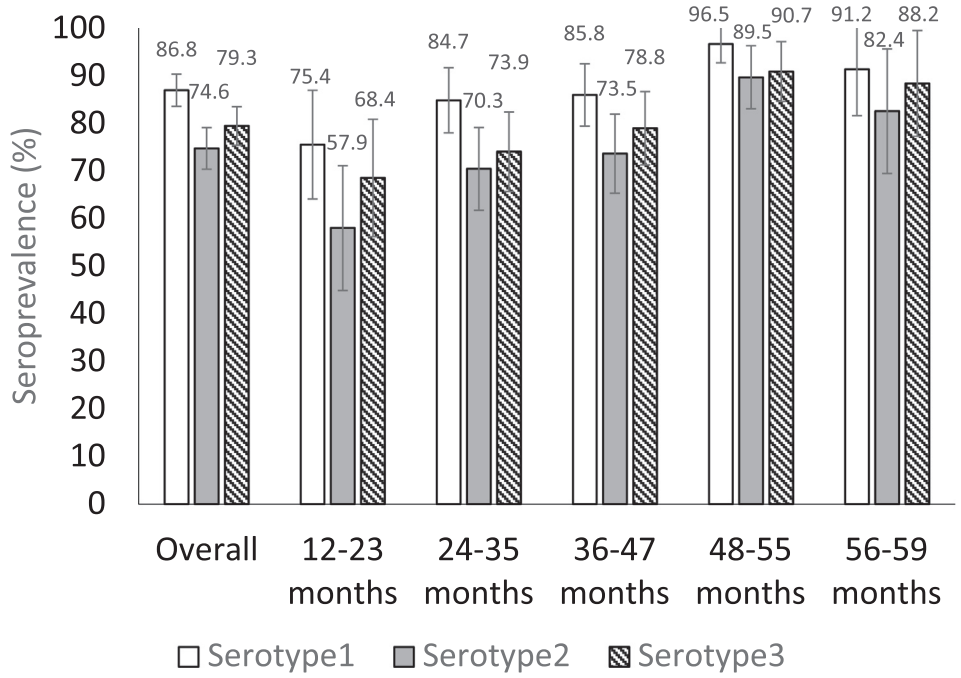

Fig. 1. Seroprevalence of all types by age groups. Children in the 56–59-month age group were born before the tOPV to bOPV switch.

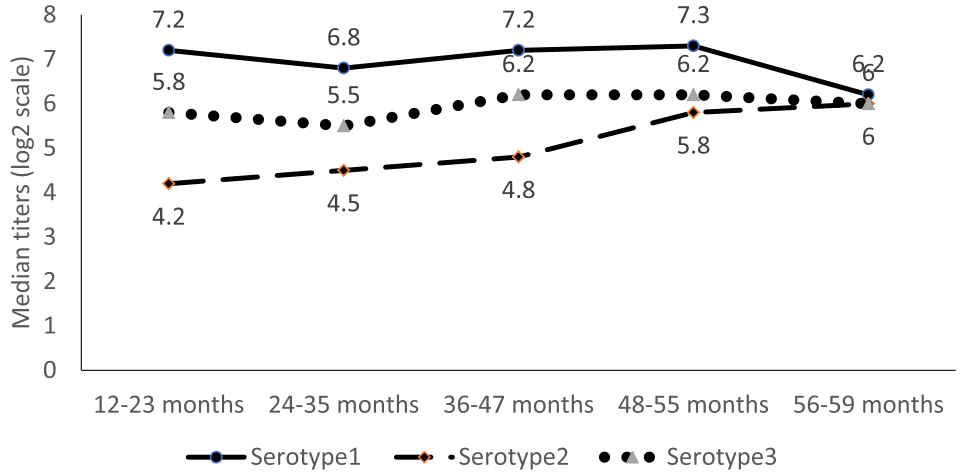

Fig. 2. Median poliovirus neutralizing antibody titers by age group. Children in the 56–59-month age group were born before the tOPV to bOPV switch.

Table 2
Median titers in $\log_2$ scale by age groups.

Age groups (in months)	Type 1		Type 2		Type 3	
	Median	95 % CI	Median	95 % CI	Median	95 % CI
12–23	7.2	5.8–9.3	4.2[a]	<3–7.5	5.8	3.8–8.2
24–35	6.8	6.2–8.2	4.5[a]	3.7–5.5	5.5	4.5–6.5
36–47	7.2	6.2–8.7	4.8[a]	4.5–5.8	6.2	5.5–7.2
48–55	7.3	6.2–7.8	5.8	5.2–6.8	6.2	5.5–7.2
56–59	6.2	4.8–7.9	6.0	4.8–7.8	6.0	4.8–7.2

[a] Comparison with 48–55 months children is statistically significant.

group (12–23 months), underlying the programmatic need to be prepared to respond to outbreaks in this age group and to strengthen RI.

Seroprevalence surveys in neighboring countries, Chad and Niger, showed similar trends, with seroprevalence increased with age for the serotype 2. The reported values in Chad for 12–23, 24–35, 36–47, 48–59 age groups was 37 %, 48 %, 65 %, 83 %, respectively.[13] For the same age intervals, Niger reported 85 %, 85 %, 89 %, 92 %.[14] Moreover, median titers for serotype 1 were high for all age groups and increased with age for serotype 2, again consistent with studies in Chad, Borno, and Yobe provinces of Nigeria. [13–15].

Table 3A
Bivariate analysis for type 2 seronegative children.

Risk factors	Type 2 Seronegative		P value
	n/N	%	
12–35 months age	57/168	33.9	**0.001***
>35to < 60 months	45/233	19.3	
IPV administered	0/34	0	1.000
IPV not administered	10/34	29.4	
Illiterate parent	50/169	29.6	0.106
Some formal education	52/232	22.4	
Nomads/Internally displaced persons	5/22	22.7	1.000
Residents	97/379	25.6	
Open defecation	7/67	10.4	**0.002***
Common / Individual toilet	95/234	28.4	

Note:
* P value < 0.01.

Table 3B
Bivariate analysis for type 1 and 3 seronegative children.

Risk factors	Type 1 Seronegative		P value	Type 3 Seronegative		P value
	n/N	%		n/N	%	
12–35 months age	31/168	18.5	**0.011***	47/168	28.0	**0.003***
>35to < 60 months	22/233	9.4		36/233	15.5	
IPV administered	3/34	8.8	1.000	8/34	23.5	1.000
IPV not administered	0/2	0.0		0/2	0.0	
Illiterate parent	19/169	11.2	0.371	32/169	18.9	0.533
Some formal education	34/232	14.7			22.0	
				51/232		
Nomads/Internally displaced persons	2/22	9.1	0.752	5/22	22.7	0.789
Residents	51/379	13.5		78/379	20.6	
Open defecation	6/67	9.0	0.325	9/67	13.4	0.136
Common / Individual toilet	47/334	14.1		74/344	22.2	

Note:
* P value < 0.01.

Hygiene and level of parental education are factors that continuously arise as associations with seropositivity.[13,16,17] Using toilets at both household- and community- level facilities revealed to be a risk factor in this study; children who defecated in open fields had a higher chance of being seropositive for type 2 poliovirus, consistent with reports from Chad[13]. We hypothesize that open-field defecation can lead to exposure to poliovirus explaining the higher levels of seropositivity. A report from Vietnam stresses this idea that hygiene and toilet conditions are an important factor to control transmission of polio virus[18,19]. On another hand, the educational status of the mother was likely associated with type 2 seropositivity. A mother's having formal education has been reported to influence and promote immunization activities[20].

Cameroon primarily relies on mass vaccination campaigns for poliovirus outbreak control rather than routine immunization. [21] SIAs administering mOPV2 have the risk of seeding new cVDPV2 outbreaks when immunization coverage is not optimum. [4,22] However, SIAs are instrumental for immunization mop-ups, populations with difficult access (i.e., nomadic lifestyle or hostile terrains), communities with high vaccine hesitancy and countries with destabilized health infrastructures.

There were some limitations in the study. The required sample size of the study was near 500 children however there were only 401 children enrolled. This was because households within structures selected using GIS were empty at the time of data collection. Although attempts were made to reach out to the nearby households in the structure, it was not always possible to find children in the eligible age group. The IPV history was taken only among those parents who presented with a vaccination card from RI, which was only the case in 9 % of participants. Moreover, doses received from SIAs were reported based on parental recall, which could lead to over/under estimations. The other limitation of the study was prolonged delay in test results due to delayed enrollment of children into the study due to the COVID-19 pandemic.

Table 4
Adjusted analysis for type 2 seronegative children.

Risk Factors	OR	95 % CI	P value
12–35 months age vs > 35 months age of the child	2.20	1.38–3.50	**<0.001***
Illiterate vs some formal education of the parent	1.58	0.99–2.53	0.055
Open defecation vs individual or common toilet	0.26	0.11–0.60	**0.002***

Note:
* P value < 0.01.

5. Conclusion

Our study provides evidence that despite repeated opportunities for immunization through RI and SIAs with poliovirus vaccines, the resulting antibody seroprevalence does not exceed 90 % for any serotype. Cameroon remains at risk of poliovirus importation and VDPV emergence; if such an event should occur, the spread of the virus can cause paralytic poliomyelitis outbreaks. Immunization program in Cameroon should focus on strengthening RI and, in case of future poliovirus vaccination campaigns, ensure that

the vaccine reaches all children in the targeted age groups, especially those who are hard to reach (IDPs, nomads, refugees).

Funding

Rorld Health Organization.

Disclaimer

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the contributing agencies.

This activity was reviewed by CDC and was conducted consistent with applicable federal law and CDC policy. (See e.g., 45C.F.R. part 46, 21C.F.R. part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq.).

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We wish to acknowledge the hard work of the research team (Ahanda Anicet Stéphane, Kamga Njilé Daniel, Elangue Annie, Mboké Eric, Nembot Raoul and Hassan Ben Bachir) in Cameroon for performing the sample collection, building the database and sending the samples to the CDC Atlanta. We are thankful to the Cameroon WHO country office to have provided their support to implement the study. We also thank the following CDC staff from the Polio and Picornavirus Laboratory Branch for performing the neutralization testing: William Hendley, Kathryn Jones, Sharla McDonald, Deborah Moore, Ashley Smith, and Yiting Zhang. We thank Rotary International Polioplus Committee (IPPC) through World Health Organization for providing financial support to implement this survey. Most of all, we wish to acknowledge the children and their parents for agreeing to participate in the survey

References

[1] GPEI. GPEI-Global eradication of wild poliovirus type 2 declared. 2015.
[2] CDC. Global Certification of Eradication of Indigenous Wild Poliovirus Type 3. CDC - Global Immunization - News and Views. 2019 2022-03-18T09:47:31Z.
[3] WHO. Africa eradicates wild poliovirus Brazaville: @WHOAFRO; 2020 [Available from: https://www.afro.who.int/news/africa-eradicates-wild-poliovirus, accessed September 16 2022].
[4] Macklin GR, O'Reilly KM, Grassly NC, et al. Evolving epidemiology of poliovirus serotype 2 following withdrawal of the serotype 2 oral poliovirus vaccine. Science 2020;368:401–5.
[5] Pons-Salort M, Burns CC, Lyons H, et al. Preventing Vaccine-Derived Poliovirus Emergence during the Polio Endgame. PLoS Pathog 2016;12(7):e1005728.
[6] WHO, GPEI. Global Wild Poliovirus 2016-2021 GPEI2021 [updated 30 November 2021. Available from: https://polioeradication.org/wp-content/uploads/2021/12/weekly-polio-analyses-WPV-20211130.pdf accessed September 16 2022].
[7] GPEI. Global Circulating Vaccine-Derived Poliovirus (cVDPV)- December 2021: World Health Organization (WHO); 2021 [Available from: https://polioeradication.org/wp-content/uploads/2021/12/weekly-polio-analyses-cVDPV-20211207.pdf accessed September 16 2022].
[8] Bigna JJR. Polio eradication efforts in regions of geopolitical strife: the Boko Haram threat to efforts in sub-Saharan Africa. Afr Health Sci 2016;16(2):584–7.
[9] Unicef. Country Office Annual Report 2020 - Cameroon. 2020.
[10] Unicef, WHO. Cameroon: WHO and UNICEF estimates of immunization coverage: 2020 revision. WHO and Unicef; 2021.
[11] Icf INS. Enquete Demographique et de Sante 2018 - indicateurs cles 2018. Yaoundé, Cameroun et Rockville, Maryland, USA : INS et ICF.: Institut National de la Statistique et ICF; 2020.
[12] PASS 14 Power Analysis and Sample Size Software. Kaysville, Utah, USA: NCSS, LLC; **2015**.
[13] Gamougam K, Jeyaseelan V, Jones KAV, et al. A Survey to Assess Serological Prevalence of Poliovirus Antibodies in Areas With High-Risk for Vaccine-Derived Poliovirus Transmission in Chad. Journal of the Pediatric Infectious Diseases Society 2022;11(2):55–9.
[14] Ousmane S, Ibrahim DD, Goel A, et al. Achieving High Poliovirus Antibody Seroprevalence in Areas at Risk of Vaccine-Derived Poliovirus Transmission—Niger Experience. Open Forum. Infect Dis 2021;8(7):ofab210.
[15] Gofama MM, Verma H, Molodecky N, et al. Survey of poliovirus antibodies in Borno and Yobe States, North-Eastern Nigeria. PLoS One 2017;12(9):e0185284.
[16] Opare JKL, Akweongo P, Afari EA, Odoom JK. Poliovirus neutralizing antibody levels among individuals in three regions of Ghana. Ghana Med J **2019**;53(2):PMC6697761.
[17] Iliyasu Z, Nwaze E, Verma H, et al. Survey of poliovirus antibodies in Kano. Northern Nigeria Vaccine 2014;32(12):1414–20.
[18] Coates K. Want to Stop Polio? Vaccines are Crucial. But So Are Toilets. UN Dispatch. 2016 2016-03-09.
[19] Joi P. The last mile of polio eradication and the vaccination challenges it brings: Gavi - Vaccines Work; 2020 [Available from: https://www.gavi.org/vaccineswork/last-mile-polio-eradication-and-vaccination-challenges-it-brings accessed September 16 2022].
[20] Waters HR, Dougherty L, Tegang SP, et al. Coverage and costs of childhood immunizations in Cameroon. Bull World Health Organ 2004;82(9):668–75.
[21] Ames H, Njang DM, Glenton C, et al. Mapping how information about childhood vaccination is communicated in two regions of Cameroon: What is done and where are the gaps? BMC Public Health 2015;15(1):1–12.
[22] Alleman MM, Jorba J, Greene SA, et al. Update on Vaccine-Derived Poliovirus Outbreaks — Worldwide, January 2020–June 2021. MMWR - Morb Mortal Wkly Rep 2021;70(49):1691–9.