

**Survey of Poliovirus Antibodies in Kano, Northern Nigeria**

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Funding: Provided by the World Health Organization

Conflict of interest: No authors reported a conflict of interest.

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## **ABSTRACT**

Introduction: In 1988, the World Health Assembly resolved to eradicate poliomyelitis. Since then, much progress towards this goal has been made, but three countries remain polio-endemic, including Nigeria. To assess the reasons for the transmission in Northern Nigeria, we conducted a seroprevalence survey in the Kano Metropolitan Area.

Methods: Parents or guardians of infants aged 6-9 months or children aged 36-47 months presenting to the Outpatient Department of Murtala Mohammad Specialist Hospital were approached for participation, screened for eligibility and were asked to provide informed consent. After that, a questionnaire was administered and blood was collected for neutralization assay.

Results: A total of 327 subjects were enrolled. Of these, 313 (96%) met the study requirements and were analyzed (161 [51%] aged 6-9 months and 152 [49%] aged 36-47 months). Among subjects aged 6-9 months, seroprevalence was 81% (95% confidence interval [CI] 75-87%) to poliovirus type 1, 76% (95% CI 68-81%) to poliovirus type 2, and 73% (95% CI 67-80%) to poliovirus type 3. Among subjects aged 36-47 months, the seroprevalence was 91% (95% CI 86-95%) to poliovirus type 1, 87% (95% CI 82-92%) for poliovirus type 2, and 86% (95% CI 80-91%) to poliovirus type 3. Seroprevalence was associated with history of OPV doses, maternal education and gender.

Conclusions: Failure-to-vaccinate and not vaccine failure accounts for the suboptimal seroprevalence in Nigeria. Given the continued occurrence of poliomyelitis in both age groups in Kano, intensified efforts are necessary to administer polio vaccines to all target children and surpass the threshold levels for herd immunity.

## INTRODUCTION

Over two decades have passed since the World Health Assembly resolved in 1988 to eradicate poliomyelitis by 2000 [1], and great strides have been made towards achieving this goal. By 2012, the number of polio-endemic countries has been reduced from 125 to only 3 (i.e., Afghanistan, Pakistan and Nigeria) [2] and the incidence of poliomyelitis decreased by more than 99% [3]. In early 2012 India was removed from the list of endemic countries after more than a year had passed without detection of any cases [3-4]. The last case in India, associated with poliovirus type 1, was reported from the State of West Bengal, with the date of onset of 13 January 2011 [3, 4]. The main challenges to eradicating poliomyelitis in these remaining endemic countries includes inadequate service delivery of oral poliovirus vaccine (OPV) and suboptimal OPV efficacy in the densely populated tropical reservoirs [5, 6]

Nigeria is the only country in the world that is endemic for wild poliovirus types 1 and 3 and circulating vaccine-derived poliovirus type 2 (cVDPV2) [7, 8]. Although multiple rounds of supplementary immunization activities (SIAs) are conducted each year, the coverage achieved with trivalent OPV (tOPV) was insufficient to interrupt the transmission of these viruses. More recently, to maximize the immunity per contact, more immunogenic polio vaccines were introduced, first monovalent OPV (mOPVs) in 2006, and second, bivalent (types 1 and 3) oral poliovirus vaccine (bOPV) in 2010 [9, 10].

Nigeria's polio control problems got aggravated in 2003, when despite having the highest number of polio cases in the world, planned SIAs were suspended in some Northern States because of OPV safety concerns [11]. Rumors circulated that the vaccine was deliberately tampered with anti-fertility agents and human immunodeficiency virus (HIV) [12]. Consequently, the number of poliomyelitis cases in Nigeria increased to 1,122 in 2006. This case count dropped to 285 polio cases in 2007 but in 2008, the number of cases rebounded to 798. Following

renewed efforts a downward trend was sustained throughout 2010 [2, 3]. This decline was attributed to the use of sharper tools (i.e., mOPV1, bOPV), multiple campaigns that included other vaccines and other health interventions (Immunization Plus Days) and more recently an overall improvement in the SIA quality due to the engagement of high political levels and a very systematic involvement and advocacy by the traditional and religious leadership.

However, in 2011 and 2012, there was a relative upsurge of wild poliovirus cases in Nigeria with 62 cases in 2011 and 119 in 2012 (WHO unpublished data, as of 2 January 2013). All Northern states remain endemic, including the most populous Northern State of Kano which reported 22 wild poliovirus cases and 3 cVDPV2 cases in 2012 (WHO unpublished data, as of 2 January 2013).

Although there are published reports [13-17] of seroprevalence studies in some parts of Nigeria among different age groups, no such surveys have been conducted in the recent years in Kano to provide an immunity benchmark to reflect program performance and to guide future program action.

## **Methods**

### *Selection of the study Area and the study team*

Kano state was selected because it is the most populated state in Northern Nigeria, it includes a large number of high risk LGAs, and it continues to report all three serotypes (i.e., wild poliovirus types 1 and 3, and cVDPV2). Within Kano state, we chose the eight LGAs that comprise Kano Metropolitan Area as the target area for this survey.

Murtala Mohammad Specialist Hospital (MMSH) was selected as the study site because it is the largest pediatric hospital in the area and is frequented by patients from all eight LGAs of the Kano Metropolitan Area: Kano Municipal, Fagge, Nassarawa, Dala, Gwale, Tarauni, Ungogo

and Kumbotso [Figure 1]. Aminu Kano Teaching Hospital (AKTH) Kano, a university hospital, took the lead for this survey in collaboration with MMSH.

### *Study objectives*

The objectives of this study were: (1) to assess the seroprevalence to poliovirus type 1, type 2 and type 3 among infants aged 6–9 months and children aged 36-47 months residing in the Kano Metropolitan Area of Nigeria; and (2) to evaluate specific risk factors for low seroprevalence.

### *Study setting and target population*

Parents and guardians of patients visiting the pediatric outpatient department (POPD) of MMSH were approached for possible participation in this survey. MMSH is a state government-run hospital with a very high turnover in the POPD. Patients come from a very wide catchment area with a mixed socioeconomic background.

### *Routine and supplemental immunization activities*

Subjects aged 36-47 months were potentially exposed to a much higher number of SIAs than infants aged 6-9 months . However, the number of campaigns and the type of vaccine could be ascertained far more accurately for the 6-9 months age group (i.e., infants born between 20 July to 19 November 2010). A total of 8 SIAs campaigns (including one that was partial) were conducted in Kano State between July 2010 to May 2011, including 5 SIAs with bOPV and 3 SIAs with tOPV. Therefore these infants could have received 3-5 bOPV and 2-3 tOPV doses through campaigns, depending on the actual birth date. In addition, these infants and children could have received 4 doses of tOPV administered by the routine immunization services.

### *Sample size*

A total of 300 children were required for the survey. Sample size calculations were based on |20%| difference in seroprevalence between the two age groups. Considering a seroprevalence for poliovirus types 1, 2 and 3 of 40-60% and applying a power of 0.90 (beta) and alpha of 0.05 (two-tailed test), the sample size was 135 per arm. This was inflated to 150 per arm to account for possible exclusions due to insufficient sera.

### *Eligibility criteria*

Infants aged 6–9 months or children 36-47 months living for at least one month in the eight LGAs of Kano Metropolitan Area with consenting care-givers were eligible to participate, except those (a) with a contraindication to venepuncture; (b) with serious acute illnesses requiring hospitalization; or (c) with a diagnosis or a suspicion of congenital immunodeficiency disorder in the subject or an immediate family member.

### *Enrollment and survey procedures*

The selection of participants required initial screening for age and area of residence. Enrollment started on 19 May and was completed on 2 June 2011. For the study purpose, three study clinics were set up in three different rooms in the vicinity of the OPD. Each study clinic had independent study staff who were responsible for all study procedures. The study staff was drawn from the pediatrics, laboratory and general staff of the AKTH and MMSH. The POPD doctors after providing the consultation and the medical advice, directed the parents or guardians to the study staff at the clinic's exit. This study staff, a senior matron of the hospital, supervised by one of the investigators, screened all children for eligibility by age and place of residence. Patients potentially fulfilling the age and residence criteria were directed to one of

the study clinics in the order they were becoming available. The study physician in the study clinic explained the study to the parents or guardians and assessed children on inclusion/exclusion criteria. After obtaining informed consent of caretakers, weight and length/height were measured, immunization history taken and the questionnaire was completed.

#### *Blood collection and antibody testing procedures*

One ml of blood was collected through venepuncture into a vacutainer tube with clot separator by an experienced pediatric resident or a phlebotomist. Serum was separated within 6 hours at AKTH and stored at  $-20^{\circ}\text{C}$  in a deep freezer. At the end of the study, samples were shipped in dry ice using professional courier services to the Centers for Disease Control and Prevention (CDC) in Atlanta. Sera were tested in triplicate for levels of neutralizing antibody titers against poliovirus types 1, 2 and 3, respectively, using modified micro-neutralization assays previously described [18, 19]. Unobserved titers (below the starting and above the ending dilution) were assigned values of  $<8$  and  $\geq 1448$ , respectively.

#### *Definitions*

The number of OPV doses received by the study subjects was recorded, based on verbal recall because immunization cards were not available with the parents. History was taken by the study physicians separately for routine and the campaign doses. Total vaccination doses were the sum of routine and SIA doses. Doses were included regardless of how close they were in time to other doses. Nutritional status was measured using height, weight and age. Height was measured using standard measuring boards; weight was measured using scales at each recruitment clinic. Data were compared to the standard distribution of a reference population

using Epi Info software [20]. The reference population was the Centers for Disease Control and Prevention (CDC)'s National Center for Health Statistics standard recommended for international use by UNICEF and WHO [21]. Categories of malnutrition were based on standard deviation (SD) units (z-scores) below the mean of the reference population. These categories were defined as normal ( $<2$  SD), severe to moderate (2.0–2.9 SD) and extreme ( $\geq 3$  SD). *Stunting* (low height-for-age) is a measure of chronic malnutrition; *wasting* (low weight-for-height) is a measure of acute malnutrition.

#### *Data management and statistical analysis*

Questionnaires were double-entered into an initial database using EpiInfo software [20]. Data analysis was done using SAS version 9.2 by CDC, Atlanta [23]. Chi-square tests were used to determine factors that were significantly associated with seroprevalence in univariate analysis. Logistic regression was used to obtain adjusted odds ratios and assess the association of other risk factors (gender, education level, nutrition, etc.) on seroprevalence by number of vaccine doses received.

## **RESULTS**

#### *Recruitment, exclusions and final study sample*

Between 19 May and 2 June 2011 a total of 327 subjects were enrolled. One subject was found to be ineligible after having been allotted an ID number (A032), and adequate blood samples could not be collected from 12 subjects. Therefore, 314 serum were available for analysis.

However, one subject had missing data on age (and was excluded). Therefore, the final study group consists of 313 subjects, 161 (51%) in the 6-9 month age group and 152 (49%) in the 36-47 month age group.

### *Characteristics of study subjects*

The median ages were 8 and 41 months for infants aged 6-9 months and children aged 36-47 months, respectively. The demographic characteristics, nutritional indices and routine and campaign OPV dose histories are shown in Table 1. Males accounted for approximately half of the participants in both age groups. The proportion of mothers with low educational status (primary or less) was quite high (62% in older age group compared to 52% in the younger age group). Wasting was found in 20% of subjects and moderate to severe stunting in 47% of participants.

### *Seroprevalence*

The overall seroprevalence levels for poliovirus types 1, 2 and 3 poliovirus were 81% (95% confidence intervals [CI] 75-87%), 76% (95% CI 68-81%) and 73% (95% CI 67-80%) respectively in the 6-9-month age group and 91% (95% CI 86-95%), 87% (95% CI 82-92%) and 86% (95% CI 80-91%) in the 36-47-month age group [Figure 2].

### *Risk factors*

In the 6-9 months age group, the univariate analysis showed significant association of seroprevalence of all the three types with the number of routine, SIA and the total OPV doses received. For types 2 and 3, there was also a significant association between mother's educational status and seropositivity. Although male gender tended to have higher seroprevalence for the three types, these differences were not statistically significant. Only 96 (60%) out of 161 infants were seropositive to all 3 serotypes and 16 (10%) to none. Out of the 16 infants that were seronegative to all 3 types, 11 received less than 4 OPV doses, 12 had mothers

with primary education or less and 9 had moderate to severe stunting. There was an association between mother's education and total doses received. Subjects whose mothers had secondary or tertiary education tended to have more total doses of OPV.

In the 36-47 months age group, the univariate analysis showed also significant association between seropositivity to all the three serotypes with the number of the total OPV doses received. Types 1 and 3 seropositivity was associated with SIA doses and for type 2, it was associated with routine OPV doses. For type 2, there was also a significant association between mother's educational status and seropositivity. Only 112 (60%) out of 152 were seropositive to all 3 serotypes and 4 (3%) were seronegative to all three. Association between number of OPV doses and the seroprevalence in the two age groups can be seen in the Tables 3 and 5.

Table 4 shows that for infants aged 6-9 months, after adjusting for confounding effects of other variables, routine immunization doses and SIA doses remained significant predictors of seropositivity to type 1 poliovirus. Each additional routine immunization dose increased the odds of seropositivity by nearly half (48%). Similarly, subjects that received one dose of SIA had a three-fold increased odds of being seropositive against poliovirus type 1. For type 2, only total (routine and SIA) vaccine doses was a significant predictor of seropositivity. Infants that received 4-6 total doses had nearly eleven times (10.96) higher odds to have protective antibodies compared to zero-dose infants. Similarly, infants that received 7 or more total doses had more than 44 times higher odds to be seropositive to type 2 compared to zero dose infants. However, when the 7 or more total dose infants were compared with those that received 4-6 doses, the higher dose infants had more than four-fold higher odds to be seropositive. Similarly, when 7 or more total dose infants were compared with 1-3 total dose infants, the highest dose infants had more than seven-fold higher odds to have protective antibodies to type 2.

For children in the 36-47 months age group, the multivariate analyses (Table 5) confirmed that routine immunization doses, gender and mother's education remained significant predictors of seropositivity to poliovirus type 2 after adjusting for other variables. Subjects that received any additional routine dose of the polio vaccine had a more than 50% higher odds to be seropositive to type 2. Similarly, male subjects had nearly four-times (3.83) higher odds to be seropositive compared to female subjects. Considering mother's education, subjects whose mothers had secondary or tertiary education had four times higher odds to be seropositive to type 2 compared to those whose mothers had primary school education or less.

## **DISCUSSION**

Our survey confirms that substantial immunity gaps to all three polioviruses exist in these study populations residing in the Kano Metropolitan Area in Northern Nigeria. Despite intensive efforts to increase immunity levels in Nigeria since the introduction of SIAs in 1996, the prevalence of antibodies against poliovirus type 1 in both age groups tested (81% in the 6-9 months age group and 91% in the 36-47 months age group) remains at levels that are insufficient to interrupt poliovirus transmission. .

The low seroprevalence among 6-9-month old infants reflects the current programmatic problems in Northern Nigeria with suboptimal vaccination coverage, while the seroprevalence 36-47month children reflects a longstanding vaccination problem and a possible future problem with relatively low seroprevalence levels , much lower than in corresponding serosurveys in Egypt and India [23, 24].

Nevertheless, in both age groups evaluated, an increasing number of routine and campaign doses resulted in increasing levels of seroprevalence. Having received >7 total doses of polio vaccine provided >90% seroprevalence to poliovirus type 1 in both age groups. This

confirms the effectiveness of OPV in inducing immunity also in these populations in Northern Nigeria.

In terms of risk factors other than low vaccination histories, lower seroprevalence was associated with female gender, lower maternal education, and having fewer children in the household. While maternal education and fewer children in the household are probably not amenable to immediate intervention, social communication strategies should address the substantial gender difference of 11% to type 1 in the 6-9 month age group.

Maternal education as a proxy for socioeconomic status appears to be good predictor of the immunization status of their off-springs. The difference are most pronounced for poliovirus type 2 (14.3% in the 6-9 month age group, and 12.9% in the 36-37 month age group), probably because of better compliance with routine immunization recommendations.

In contrast to other surveys [23, 24] in Egypt and India, the nutritional status did not seem to affect the seroprevalence levels in Nigeria, for reasons which are not immediately apparent. In fact wasting or stunting was not associated with seroprevalence levels to any serotype in the 6-9-month age group. In the 36-37-month age group, severe wasting, although the numbers were small, and severe stunting was associated with lower seroprevalence levels (but not significantly).

Our study had a number of limitations, including the selection of the study population and the data collection. This study was not population-based and thus it may be difficult to generalize these findings. Nevertheless, our survey demonstrated that in our study population with access to care in a general government hospital, the seroprevalence rates were suboptimal. It is probably safe to assume that the seroprevalence levels could be lower in populations without access to care. In terms of data collection, we had to rely on parental recall for a number of variables, including vaccination histories, maternal education, and age.

Compared with other seroprevalence surveys against polioviruses conducted in Egypt and India immediately before transmission was interrupted in 2006 and 2011, respectively, this survey suggests that further efforts are needed in children <5 years in Northern Nigeria to reach the levels that were needed in Egypt and India (>98% to poliovirus type 1) [23, 24]. While the exact threshold immunity to invoke herd immunity are not known for Northern Nigeria, it must be somewhere between the current levels (81% for the 6-9 months age group) and levels reported from Egypt and India (98%-99%).

To achieve these immunity levels, both routine and SIAs vaccination coverage must substantially be increased. The ongoing transmission of wild poliovirus type 1, vaccine-derived type 2, and wild poliovirus type 3 indicates the magnitude of the problem, and strongly suggests that the seroprevalence levels against type 1 and type 3 are also likely below the threshold levels for herd immunity [25, 26]. Our survey suggests that substantially increased efforts are necessary to augment population immunity in Northern Nigeria in order to interrupt transmission of all three circulating poliovirus serotypes and achieve eradication.

#### ACKNOWLEDGEMENTS

We acknowledge the contributions of Drs Safiya Gambo, Halima Adamu and Yunusa Sanusi (Research Physicians), Nasiru Magaji Sadiq, Amina Ibrahim Muhammad (Laboratory Scientists/Phlebotomists) and Matron Hadiza Umar (Research Nurse) to the successful conduct of this survey.

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Figure 1: Study area, Kano State, Northern Nigeria, 2011

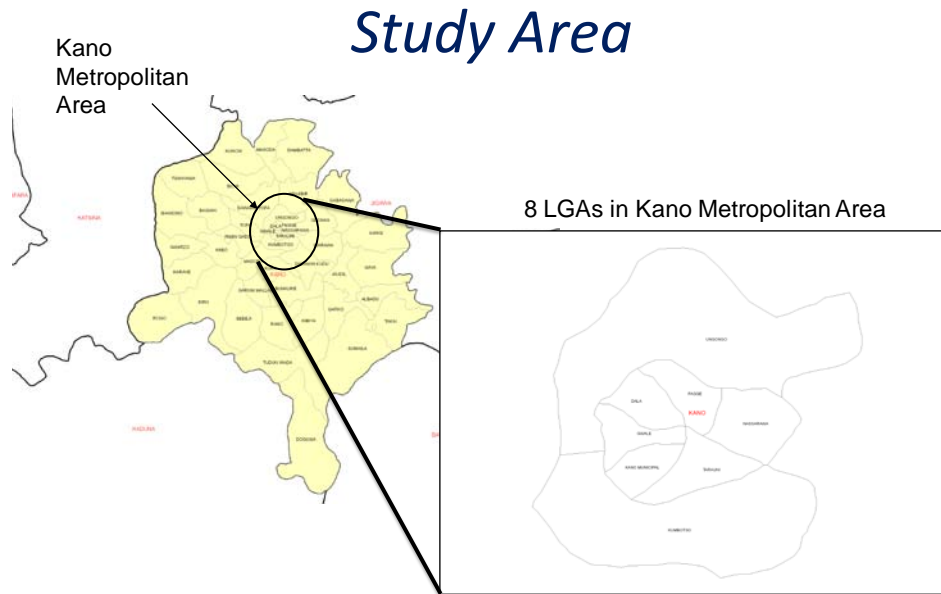


Figure legend: Seroprevalence and 95% confidence intervals, by poliovirus serotype and age group, Kano Metropolitan Area, Northern Nigeria, 2011

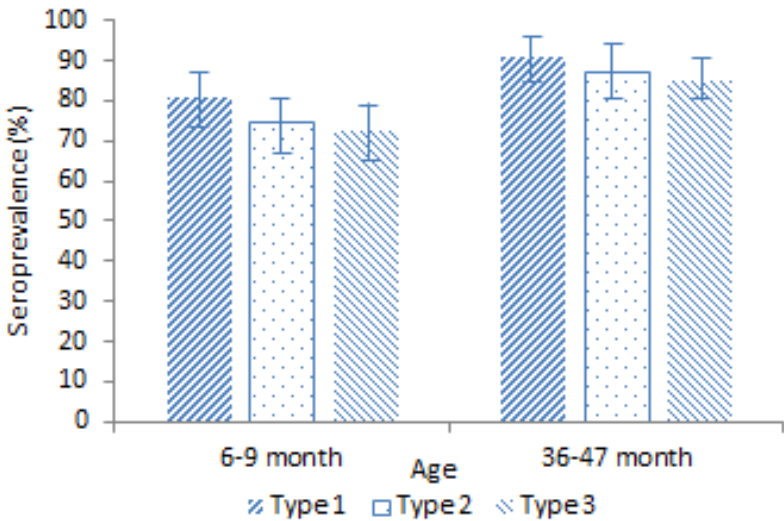


Table 1: Demographic and other attributes of study population, Kano Metropolitan Area, Northern Nigeria, 2011

Attribute	Prevalence N (%)	
	Age 6-9 months n = 161	Age 36-47 months n = 152
<b>Gender</b>		
Male	79/159 (49.7)	83/149 (55.7)
Female	80/159 (50.3)	66/149 (44.3)
<b>Mother's education</b>		
Primary or less	84/160 (52.5)	94/152 (61.8)
Secondary or tertiary	76/160 (47.5)	58/152 (38.2)
<b>No. of children aged &lt;5 yrs in household</b>		
1-2	118/157 (75.2)	124/152 (81.6)
>2	39/157 (24.8)	28/152 (18.4)
<b>Wasting</b>		
1 – no	129/155 (83.2)	120/148 (81.1)
2 – moderate	18/155 (11.6)	22/148 (14.9)
3 –severe	8/155 (5.2)	6/148 (4.1)
<b>Stunting</b>		
1 – no	76/148 (51.4)	78/145 (53.8)
2 – moderate	34/148 (23.0)	38/145 (26.2)
3 –severe	38/148 (25.7)	29/145 (20.0)
<b>Routine OPV doses</b>		
0	18/143 (12.5)	27/121 (22.3)
1	14/143 (9.7)	5/121 (4.1)
2	27/143 (18.8)	12/121 (9.9)
3	39/143 (27.1)	23/121 (19.0)
4	46/143 (31.9)	54/121 (44.6)
<b>SIAs OPV doses</b>		
0	31/155 (20.0)	5/148 (3.4)
1-3	69/155 (44.5)	26/148 (17.6)
4-6	53/155 (34.2)	31/148 (21.0)
≥ 7	2/155 (1.3)	86/148 (58.1)
<b>Total doses (RI and SIAs)</b>		
0	6/139 (4.3)	3/136 (2.2)
1-3	36/139 (25.9)	10/136 (7.4)
4-6	50/139 (36.0)	17/136 (12.5)
≥ 7	47/139 (33.8)	106/136 (77.9)

**Table 2: Seroprevalence among subjects aged 6-9 months, by demographic or other attributes, Kano Metropolitan Area, Northern Nigeria, 2011**

	Seroprevalence to poliovirus		
	type 1	type 2	type 3
	n (%)	n (%)	N (%)
<b>Gender</b>			
Male	68 (86.1)	62 (78.5)	59 (74.7)
Female	60 (75.0)	56 (70.0)	57 (71.3)
<b>Mother's education</b> <sup>2,3</sup>			
Primary or less	64 (76.2)	56 (66.7)	54 (64.3)
Secondary/tertiary	65 (85.5)	63 (82.9)	63 (82.9)
<b>No. of children &lt;5 yrs in household</b>			
1-2	94 (79.7)	83 (70.3)	84 (71.2)
>2	32 (82.1)	33 (84.6)	30 (76.9)
<b>Wasting</b>			
1 – no	105 (81.4)	96 (74.4)	95 (73.6)
2 – moderate	15 (83.3)	15 (83.3)	15 (83.3)
3 – severe	6 (75.0)	5 (62.5)	4 (50.0)
<b>Stunting</b>			
1 – no	64 (84.2)	60 (79.0)	57 (75.0)
2 – moderate	28 (82.4)	24 (70.6)	26 (76.5)
3 – severe	29 (76.3)	26 (68.4)	24 (63.2)
<b>Routine OPV doses</b> <sup>1,2,3</sup>			
0	10 (55.6)	7 (38.9)	5 (27.8)
1	12 (85.7)	8 (57.1)	7 (50.0)
2	19 (70.4)	18 (66.7)	21 (77.8)
3	34 (87.2)	35 (89.7)	34 (87.2)
4	41 (89.1)	40 (87.0)	39 (84.8)
<b>SIAs OPV doses</b> <sup>1,2,3</sup>			
0	19 (61.3)	20 (64.5)	18 (58.1)
1-3	55 (79.7)	46 (66.7)	49 (71.0)
≥ 4 <sup>a</sup>	50 (90.9)	48 (87.3)	46 (83.6)
<b>Total doses (RI and SIAs)</b> <sup>1,2,3</sup>			
0	3 (50.0)	1 (16.7)	-
1-3	24 (66.7)	21 (58.3)	20 (55.6)
4-6	40 (80.0)	38 (76.0)	39 (78.0)
≥ 7	44 (93.6)	43 (91.5)	43 (91.5)

1 Covariate significantly associated with seropositivity to TYPE 1 for  $\alpha=0.05$

2 Covariate significantly associated with seropositivity to TYPE 2 for  $\alpha=0.05$

3 Covariate significantly associated with seropositivity to TYPE 3 for  $\alpha=0.05$

a: collapsed 4-6 and  $\geq 7$  because of sparse cell counts

&The superscripts indicate which type was found to be associated with the variable.

**Table 3: Seroprevalence among subjects aged 36-47 months, by demographic or other attribute, Kano Metropolitan Area, Northern Nigeria, 2011**

	Seroprevalence to poliovirus		
	type 1	type 2	type 3
<b>Gender</b>	n (%)	n (%)	n (%)
Male <sup>2</sup>	76 (91.6)	77 (92.8)	69 (83.1)
Female	59 (89.4)	53 (80.3)	58 (87.9)
<b>Mother's education<sup>2</sup></b>			
Primary or Less	86 (91.5)	77 (81.9)	77 (81.9)
Secondary/Tertiary	52 (89.7)	55 (94.8)	53 (91.4)
<b>No. of children &lt;5 yrs in household</b>			
1-2	113 (91.3)	110 (88.7)	106 (85.5)
>2	25 (89.3)	22 (78.6)	24 (85.7)
<b>Wasting</b>			
1 – no	109 (90.8)	107 (89.2)	103 (85.8)
2 – moderate	19 (86.4)	17 (77.3)	18 (81.8)
3 – severe	6 (100)	5 (83.3)	5 (83.3)
<b>Stunting</b>			
1 – no	72 (92.3)	70 (89.7)	67 (85.9)
2 – moderate	32 (84.2)	31 (81.6)	30 (79.0)
3 – severe	27 (93.1)	25 (86.2)	26 (89.7)
<b>Routine OPV doses<sup>2</sup></b>			
0	23 (85.2)	19 (70.4)	21 (77.8)
1	4 (80.0)	4 (80.0)	2 (40.0)
2	12 (100)	10 (83.3)	9 (75.0)
3	20 (87.0)	23 (100)	21 (91.3)
4	51 (94.4)	48 (88.9)	47 (87.0)
<b>SIA's OPV doses<sup>1,3</sup></b>			
0	4 (80.0)	4 (80.0)	4 (80.0)
1-3	22 (84.6)	21 (80.8)	18 (69.2)
4-6	27 (87.1)	26 (83.9)	26 (83.9)
≥ 7	82 (95.4)	77 (89.5)	78 (90.7)
<b>Total doses (RI and SIA's)<sup>1,2,3</sup></b>			
0	2 (66.7)	2 (66.7)	2 (66.7)
1-3	8 (80.0)	6 (60.0)	5 (50.0)
4-6	14 (82.4)	16 (94.1)	14 (82.4)
≥ 7	100 (94.3)	94 (88.7)	93 (87.7)

1 Covariate significantly associated with seropositivity to TYPE 1 for  $\alpha=0.05$

2 Covariate significantly associated with seropositivity to TYPE 2 for  $\alpha=0.05$

3 Covariate significantly associated with seropositivity to TYPE 3 for  $\alpha=0.05$

NOTE: exact trend test for dose variables in 36-47 month old group

NOTE: among the 36-47 month group, mother's education is associated with routine, SIA and total doses.

&The superscripts indicate which type was found to be associated with the variable.

**Table 4: Predictors of seropositivity among subjects aged 6-9 months, Kano Metropolitan Area, Northern Nigeria, 2011**

<b>Type 1 (n=139)</b>	Type III P value <sup>1</sup>	Comparison	Odds Ratio	Lower 95% CI	Upper 95% CI
RI Dose (continuous)	0.013	Each additional dose	1.48	1.09	2.01
Any campaign dose	0.022	≥1 SIA dose v. 0 SIA doses	3.00	1.17	7.70
<b>Type 2 (n=136)</b>					
Total Doses (RI & SIA)	0.004	1-3 v. 0	6.27	0.62	63.70
		4-6 v. 0	10.96	1.02	117.30
		≥7 v. 0	44.29	3.77	520.90
		≥7 v. 4-6	4.04	1.15	14.19
		≥7 v. 1-3	7.07	2.02	24.70
		4-6 v. 1-3	1.75	0.64	4.77
Mother's education	0.058	Secondary/Tertiary v. ≤ Primary	2.46	0.97	6.22
No. of children <5yrs in household	0.087	>2 v. 1-2	2.65	0.87	8.08
<b>Type 3 (n=139)</b>					
RI dose (continuous)	<0.001	Each additional dose	2.02	1.48	2.76
Any campaign dose	0.048	≥1 SIA dose v. 0 SIA doses	2.62	1.01	6.82

<sup>1</sup> Type III Chi-square p-value is a test of significance given the other variables are in the model.

**Table 5: Predictors of seropositivity among subjects age 36-47 months, Kano Metropolitan Area, Northern Nigeria, 2011**

<b>Type 1</b>	Type III Pvalue <sup>1</sup>	Comparison	OR	Lower 95% CL	Upper 95% CL
<b>Type 2 – MODEL 2 N=148</b>					
Sex	0.017	Male v. Female	4.02	1.28	12.56
Mother's Education	0.024	Secondary/Tertiary v. ≤ Primary	4.02	1.28	12.56
Wasting	0.083	Moderate v. None	0.23	0.06	0.87
		Severe v. None	0.32	0.03	3.80
		Severe v. Moderate	1.35	0.10	18.10
<b>Type 3 – Model 1</b>					
Total Doses (RI & SIA) N = 136	0.037	1-3 v. 0	0.50	0.03	7.45
		4-6 v. 0	2.33	0.16	34.89
		≥7 v. 0	3.58	0.30	42.27
		≥7 v. 4-6	1.53	0.39	6.07
		≥ v. 1-3	7.16	1.82	28.12
		4-6 v. 1-3	4.67	0.80	27.08
<b>Type 3 – Model 2 N=148</b>					
SIA Doses	0.078	1-3 v. 0	0.56	0.05	5.86
		4-6 v. 0	1.30	0.12	12.20
		≥7 v. 0	2.44	0.24	24.53
		≥7 v. 4-6	1.88	0.56	6.24
		≥7 v. 1-3	4.33	1.43	13.10
		4-6 v. 1-3	2.31	0.65	8.22