



Research Article

Serological Screening for *Onchocerca volvulus* Exposure Using the Ov16 IgG4 Rapid Diagnostic Test among Internally Displaced Persons in Wassa Camp, Federal Capital Territory, Nigeria

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ABSTRACT

Onchocerciasis remains a priority neglected tropical disease in Africa, and internally displaced persons (IDPs) are frequently omitted from routine elimination surveillance. This descriptive cross-sectional survey assessed serological evidence of *Onchocerca volvulus* exposure among residents of Wassa IDP Camp, Federal Capital Territory (FCT), Abuja, Nigeria. Screening was conducted over three consecutive days, from 23 to 25 August 2022, using the SD Bioline Onchocerciasis IgG4 rapid diagnostic test (RDT), which detects human IgG4 antibodies against the *O. volvulus* Ov16 antigen in finger-prick whole blood. Consenting residents aged five years and above were screened consecutively, and test lines were read at the manufacturer-recommended time. Data were summarised as counts and percentages; the Clopper-Pearson exact binomial method quantified uncertainty around the prevalence estimate, and the chi-square test compared demographic distributions. A total of 361 participants were screened, comprising 120 males (33.2 %) and 241 females (66.8 %) distributed across six age categories, the largest being children aged 5–9 years (36.6 %). No Ov16 RDT-positive or invalid result was recorded in either sex, in any age group, or on any screening day. Observed seroprevalence was therefore 0.00 % (exact two-sided 95 % confidence interval 0.00–1.02 %; one-sided 95 % upper confidence limit 0.83 %). The findings indicate an absence of detectable Ov16 serological evidence of *O. volvulus* exposure among those screened. However, Periodic integrated surveillance is recommended for displaced communities in the FCT in order to satisfy the World Health Organization stop-treatment threshold of an upper confidence limit below 0.1 %.

Keywords: Internally displaced persons; Nigeria; Onchocerciasis; Ov16 IgG4; Rapid diagnostic test; Sero-surveillance

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INTRODUCTION

Onchocerciasis, commonly known as river blindness, is a parasitic disease caused by the filarial nematode *Onchocerca volvulus* and transmitted to humans through the repeated bites of infected *Simulium* blackflies. The vector breeds in fast-flowing, well-oxygenated rivers and streams, which explains the historical association between infection, riverside

farming communities and blindness in parts of West and Central Africa (Crosskey, 1956; Post *et al.*, 2011). The clinical spectrum includes intense pruritus, papular and depigmented dermatitis, subcutaneous nodules, ocular inflammation, visual impairment and irreversible blindness. Beyond its medical consequences, the disease disrupts education, agriculture, productivity and community

development because affected populations are typically rural and economically vulnerable (WHO, 2025).

The global strategy for onchocerciasis has shifted from morbidity control to interruption of transmission. This change is reflected in the World Health Organization (WHO) road map for neglected tropical diseases 2021–2030, which sets targets for reducing the need for ivermectin mass drug administration (MDA), interrupting transmission in defined foci and strengthening country-led surveillance (WHO, 2021). Progress reports show that onchocerciasis remains concentrated in Africa and Yemen, while also documenting foci where treatment has stopped and countries that have moved into post-treatment surveillance (WHO, 2024; Lakwo *et al.*, 2020). These successes make it increasingly important to detect low-level residual transmission, to identify populations omitted by routine programmes, and to interpret negative surveys with appropriate statistical caution.

Nigeria has historically carried one of the largest onchocerciasis burdens globally, but the national programme has also generated some of the clearest African evidence that sustained ivermectin distribution can interrupt transmission. Kaduna, Kebbi and Zamfara states were reported to have interrupted transmission after about two decades of consistent treatment (Isiyaku *et al.*, 2022), while Plateau and Nasarawa states progressed through post-treatment surveillance with vector pools negative for *O. volvulus* DNA (Miri *et al.*, 2022). More recently, Abia, Anambra, Enugu and Imo states met WHO epidemiological and entomological criteria for stopping MDA after approximately 25 years of treatment, representing the largest stop-treatment decision reported to date (Ityonzughul *et al.*, 2024). Progress is nevertheless uneven: persistent microfilarial infection has been documented in villages of Enugu and Ogun states after many rounds of ivermectin (Ekpo *et al.*, 2022), residual transmission has been reported in Cross River State after two decades of MDA (Chikezie *et al.*, 2023), and recrudescence of transmission has been demonstrated in Kaduna State five years after a stop-treatment decision, with insecurity-driven human migration advanced as a plausible driver (Olanrewaju *et al.*, 2025).

Internally displaced persons deserve particular attention in NTD surveillance. Displacement caused by insurgency, communal conflict, banditry, flooding or economic disruption moves people from endemic rural communities into peri-urban camps and

informal settlements. Such movement changes exposure patterns but does not automatically remove public health risk. Displaced persons may carry past exposure from their places of origin, may have had interrupted access to ivermectin, and commonly live in settings where routine health records are incomplete (Meteke *et al.*, 2020; Bestwick *et al.*, 2026). Camps also have fluid population structures and informal residence patterns that complicate denominators for MDA coverage. Nigeria hosts large displaced populations across the north-central and north-west zones, including within and around the FCT (IOM, 2023). Published serological data on onchocerciasis among displaced populations in Nigeria are scarce, and camp residents in the FCT have not previously been characterised in the peer-reviewed literature. Importantly, the FCT has historical significance for onchocerciasis: the Abuja area was the site of one of the earliest large-scale *Simulium* control schemes in Northern Nigeria (Davies, 1968), and the Gurara river system that drains the FCT-Kaduna-Niger interface continues to support vector breeding (Olanrewaju *et al.*, 2025). Serology is a central tool in elimination programmes, particularly where the goal is to detect evidence of exposure in children or in low-transmission settings. Antibody responses to the Ov16 antigen indicate exposure to *O. volvulus* and are used for elimination mapping, stop-MDA assessment and post-treatment surveillance (WHO, 2016; Richards *et al.*, 2018). Interpretation nonetheless requires caution. Ov16 antibody tests detect exposure rather than current patent infection, and antibodies may persist after infection has cleared; conversely, sensitivity may be limited in some populations and in very low-prevalence settings. Studies comparing Ov16 RDT and enzyme-linked immunosorbent assay (ELISA) platforms, examining the influence of reading time, and evaluating additional candidate antigens have emphasised that test performance, cross-reactivity and the absence of a perfect reference standard remain important diagnostic challenges (Shintouo *et al.*, 2021; Djune-Yemeli *et al.*, 2022; Nana-Djeunga *et al.*, 2022; Ekanya *et al.*, 2023; Otabil *et al.*, 2025). Therefore, this work aims to determine the serological evidence of *O. volvulus* exposure by using Ov16 IgG4 RDT kit to screen the residents of Wassa IDP Camp.

MATERIALS AND METHODS

Study Area

The survey was conducted at Wassa Internally Displaced Persons Camp, Abuja Municipal Area Council, Federal Capital Territory, Nigeria. The camp

lies behind Apo village, beyond Waru and Kabusa settlements, at approximately latitude 8° 52' 34.6" N and longitude 7° 28' 58.3" E. It is a semi-permanent settlement of predominantly farming households displaced from communities in north-central and north-eastern Nigeria, housed in a mixture of temporary and semi-permanent structures with communal water points and a small primary health facility. The FCT is relevant to onchocerciasis surveillance for two reasons: it receives displaced persons from several states with differing exposure and treatment histories, and its western and northern margins lie within the Gurara-Kaduna river system historically associated with *Simulium damnosum* sensu lato breeding (Davies, 1968; Olanrewaju *et al.*, 2025). The camp environment also offers a practical platform for integrated public health screening, because residents can be mobilised through camp leadership and humanitarian support structures.

Study Population

The study population comprised residents of Wassa IDP Camp aged five years and above who were present during the survey period and who consented to participate. Residents younger than five years were excluded, in line with the WHO convention that serological assessment of transmission uses children aged five years and older (WHO, 2016), as were persons who declined consent and those for whom finger-prick sampling was contraindicated. Participants were grouped into six age categories: 5–9, 10–19, 20–29, 30–39, 40–49 and 50 years or older. Because mobilisation was through camp leadership and participation was voluntary, the study population is best described as an accessible camp-based screening population rather than a probability sample of all camp residents.

Sample Size and Field Distribution

The minimum sample size was estimated using the Cochran formula for a single proportion, $n = Z^2 p(1-p)/d^2$, where $Z = 1.96$ for a 95 % confidence level and $d = 0.05$ the desired absolute precision. The proportion p was taken as 0.093, the cumulative Ov16 RDT seroprevalence reported for an endemic Nigerian population screened after a decade of ivermectin MDA (Surakat *et al.*, 2023). This yielded a minimum of 130 participants, which was increased to 143 after allowing for 10 % non-response. The number actually screened substantially exceeded this minimum, thereby improving the precision of the prevalence estimate consecutive field days. On each screening day, participants were enrolled consecutively as they presented at the camp screening point until the daily session closed. Age-

and sex-specific counts were recorded on standard field tally sheets for each day and subsequently aggregated.

Study Design

The study was a descriptive, camp-based cross-sectional serological survey. This design was appropriate because the objective was to measure the presence or absence of Ov16 IgG4 seropositivity in the accessible camp population at a single point in time. The design does not permit estimation of incidence, duration of infection, vector biting intensity or treatment history, and it cannot determine whether any participant harboured active adult worm infection, because the diagnostic method detects IgG4 antibody to Ov16 rather than adult worms, microfilariae or parasite DNA.

Diagnostic Method

The SD Bioline Onchocerciasis IgG4 rapid diagnostic test (Abbott/Standard Diagnostics, Republic of Korea) was used strictly according to the manufacturer protocol. The test qualitatively detects human IgG4 antibodies against the *O. volvulus* Ov16 antigen in whole blood. Trained field personnel performed the test, and results were read after the recommended incubation period of approximately 30 min. RDT results were classified as positive, negative or invalid based on the presence or absence of control and test lines.

Ov16-based serology was selected because it is portable, field-deployable, acceptable to communities and capable of revealing exposure in individuals without detectable skin microfilariae, and because it is the platform recommended for onchocerciasis elimination mapping and surveillance (WHO, 2016; Richards *et al.*, 2018; Otobil *et al.*, 2025; Shintouo *et al.*, 2021; Nana-Djeunga *et al.*, 2022; Ekanya *et al.*, 2023).

Data Analysis

Data were analysed using descriptive and inferential statistics. Counts and percentages were used to summarise the distribution of participants by screening day, age group and sex. Observed Ov16 seroprevalence was calculated as the number of positive tests divided by the total number of valid tests, expressed as a percentage. Because no positive result was recorded, uncertainty around the prevalence estimate was quantified using the Clopper-Pearson exact binomial method (Clopper and Pearson, 1934), which is the appropriate approach for a zero numerator; both the two-sided 95 % confidence interval and the one-sided 95 % upper confidence limit were computed, and the latter was compared with the rule-of-three approximation

(Hanley and Lippman-Hand, 1983). Exact upper confidence limits were also computed for each demographic stratum, so that the precision achieved within subgroups could be judged. The probability of observing zero positives under a range of hypothetical true prevalences was derived from the binomial probability mass function in order to indicate which prevalence values the survey could reasonably exclude. The chi-square test of independence was applied to the demographic distributions only, namely sex by screening day and sex by age group; because one expected cell counts in the age-by-sex table fell below five, the result was confirmed by Monte Carlo simulation with 20,000 replicates. Association testing between serostatus and demographic factors, logistic regression and risk-factor modelling were not performed, as there was no variation in the outcome variable. Statistical significance was set at $p < 0.05$.

Ethical Considerations

Ethical approval Number FHREC/2022/01/166/22-08-22 was obtained from the Health Research Ethics Committee of the Federal Capital Territory Ministry of Health, Abuja, and administrative clearance was

obtained from the camp management. Written informed consent was obtained from all adult participants; for participants below 18 years, written consent was obtained from a parent or guardian, with age-appropriate assent from the child. Participation was voluntary and participants were free to withdraw at any stage without consequence. Participants were counselled on the meaning of their results, and referral pathways were identified for any participant testing positive. The study was conducted in accordance with the principles of the Declaration of Helsinki. No individual names, personal identifiers or household-level information are reported.

RESULTS

The distribution of the 361 participants screened across the three field days is presented in Table 1, and their age and sex composition in Table 2. Stratum-specific Ov16 IgG4 RDT outcomes and the corresponding exact upper confidence limits are presented in Table 3, the overall seroprevalence and precision estimates in Table 4, and the inferential analyses in Table 5.

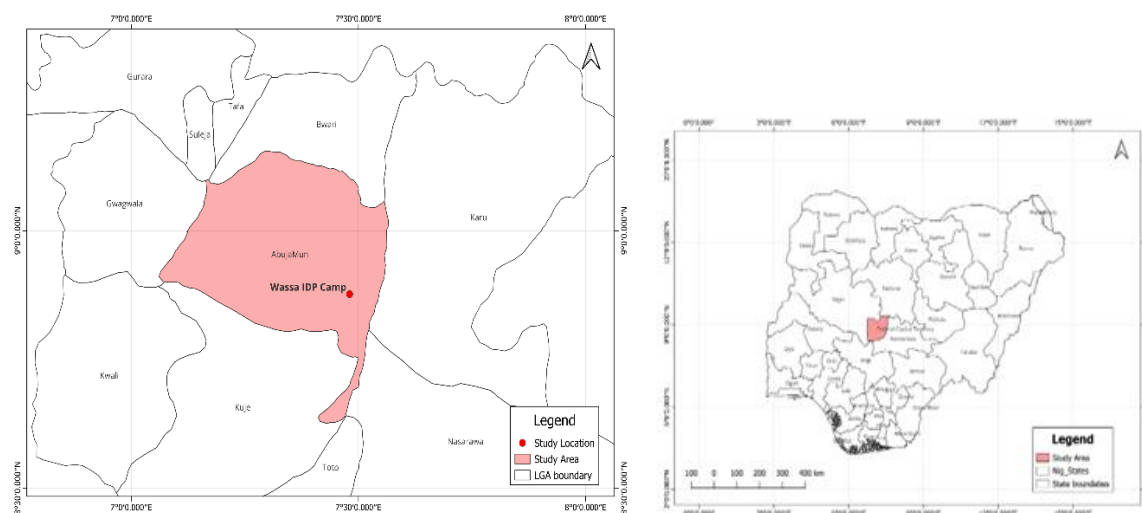


Figure 1. Map of the Study Area

Table 1: Distribution Of Screened Participants by Field Screening Day and Sex, Wassa IDP Camp

Screening day	Male, n (%)	Female, n (%)	Total, n	% of sample
Day 1	49 (29.7)	116 (70.3)	165	45.7
Day 2	30 (31.3)	66 (68.7)	96	26.6
Day 3	41 (41.0)	59 (59.0)	100	27.7
Total	120 (33.2)	241 (66.8)	361	100.0

Table 2: Age and Sex Distribution of Screened Participants

Age group (years)	Male, n (%)	Female, n (%)	Total, n	% of sample
5–9	61 (46.2)	71 (53.8)	132	36.6
10–19	30 (41.1)	43 (58.9)	73	20.2
20–29	2 (3.0)	65 (97.0)	67	18.6
30–39	15 (25.0)	45 (75.0)	60	16.6
40–49	9 (45.0)	11 (55.0)	20	5.5
≥ 50	3 (33.3)	6 (66.7)	9	2.5
Total	120 (33.2)	241 (66.8)	361	100.0

Table 3: Ov16 IgG4 Rapid Diagnostic Test Outcome by Sex, Age Group and Screening Day

Stratum	Screened, n	Positive, n (%)	Negative, n (%)	Exact 95 % UCL (%)
Sex				
Male	120	0 (0.0)	120 (100.0)	3.03
Female	241	0 (0.0)	241 (100.0)	1.52
Age group (years)				
5–9	132	0 (0.0)	132 (100.0)	2.76
10–19	73	0 (0.0)	73 (100.0)	4.93
20–29	67	0 (0.0)	67 (100.0)	5.36
30–39	60	0 (0.0)	60 (100.0)	5.96
40–49	20	0 (0.0)	20 (100.0)	16.84
≥ 50	9	0 (0.0)	9 (100.0)	33.63

UCL = exact (Clopper-Pearson) two-sided 95 % upper confidence limit for a zero numerator. The wide limits in the smaller strata indicate that subgroup estimates are imprecise and should not be interpreted individually.

Table 4: Overall Ov16 IgG4 Seroprevalence, Precision Estimates and Exclusion Probabilities

Indicator	Value
Participants screened	361
Valid tests, n (%)	361 (100.0)
Invalid tests, n (%)	0 (0.0)
Ov16 RDT positive, n (%)	0 (0.0)
Ov16 RDT negative, n (%)	361 (100.0)
Observed seroprevalence (%)	0.00
Exact two-sided 95 % confidence interval (%)	0.00–1.02
Exact one-sided 95 % upper confidence limit (%)	0.83
Rule-of-three approximation (%)	0.83
WHO stop-treatment threshold, upper confidence limit (%)	< 0.10
Probability of zero positives if true prevalence = 1.0 %	2.66 %
Probability of zero positives if true prevalence = 2.0 %	0.07 %
Probability of zero positives if true prevalence = 5.0 %	< 0.01 %

Exclusion probabilities were computed from the binomial probability mass function for the achieved sample size. WHO threshold shown for comparison only (WHO, 2016).

Table 5: Summary of inferential analyses performed

Analysis	Test statistic	Interpretation
Sex distribution by screening day	$\chi^2 = 3.82$, $df = 2$, $p = 0.148$	No statistically significant difference in the sex composition of participants across the three field days.
Sex distribution by age group	$\chi^2 = 42.76$, $df = 5$, $p < 0.001$ (confirmed by Monte Carlo simulation, $p < 0.001$)	Sex composition differed significantly across age groups, reflecting differential turnout of adult males and females.
Serostatus by sex, age group or screening day	Not estimable	No variation in the outcome variable; association testing, logistic regression and risk-factor modelling were not applicable.

DISCUSSION

This survey set out to determine the Ov16 IgG4 seroprevalence among residents of Wassa IDP Camp, to characterise the screened population, to quantify the uncertainty surrounding the estimate, and to draw implications for surveillance among displaced populations in the FCT. The discussion is organised around those four objectives.

The absence of detectable Ov16 seropositivity is, on its face, an encouraging public health signal, and it is consistent with several non-exclusive explanations. The first is that the camp population originated predominantly from areas of low transmission, or from areas where prolonged community-directed treatment with ivermectin had already suppressed exposure to levels below the detection threshold of a field serological assay. Nigeria has accumulated substantial evidence that sustained treatment can achieve this outcome, from the interruption of transmission documented in Kaduna, Kebbi and Zamfara states (Isiyaku *et al.*, 2022) and in Plateau and Nasarawa states (Miri *et al.*, 2022), to the large stop-treatment decision covering four south-eastern states (Ityonzughul *et al.*, 2024). A second explanation is ecological: the immediate environs of the camp lie on the Apo-Kabusa axis of the FCT, away from the rapids and rocky, fast-flowing reaches that support *S. damnosum* s.l. breeding, so that even individuals carrying prior infection would face little opportunity for onward local transmission. A third explanation relates to demography, in that a substantial proportion of the screened population consisted of children whose pre-displacement lives may have been too short to accumulate detectable antibody responses. A fourth possibility, which cannot be dismissed, is diagnostic: negative results may reflect the sensitivity limits of the assay rather than the true absence of exposure.

The demographic profile of the screened population carries two implications. The first concerns children.

WHO elimination assessments place particular weight on children aged five to nine years, because seroconversion in this group reflects recent rather than remote exposure and therefore serves as a sentinel for ongoing transmission (WHO, 2016; Richards *et al.*, 2018). The predominance of children in this survey is therefore epidemiologically favourable, and it strengthens the interpretation of the negative finding beyond what an adult-only survey would support. It does not, however, convert the survey into a formal stop-MDA assessment, because enrolment was by voluntary turnout at a camp screening point rather than by a structured school- or community-based sampling frame, and because both children and adults were screened together.

The second implication concerns the marked imbalance in the sex composition of the adult age groups, which was statistically significant. This pattern almost certainly reflects the daytime availability of camp residents rather than any biological difference in susceptibility: adult men were largely absent from the camp during screening hours, being engaged in farming, casual labour or trading outside the settlement. The practical consequence is a form of selection bias that is well recognised in camp-based and community-based health surveys, and it matters here for a specific reason. Adult men in displaced farming populations are frequently the group with the greatest occupational exposure to riverine environments and therefore the greatest prior risk of *O. volvulus* infection. Their under-representation means that the survey systematically under-sampled the stratum in which seropositivity would most plausibly have been found. Any future survey in this or comparable settings should schedule sessions outside working hours, use household-based enumeration, or apply a quota design to ensure adequate representation of working-age men.

The most important methodological point arising from this study concerns the interpretation of a survey in which no positive result is observed. Field reports frequently describe such findings as demonstrating that a community is free of disease. That formulation is scientifically indefensible, because a zero numerator does not eliminate sampling uncertainty; it merely places the point estimate at the boundary of the parameter space. The appropriate response is to report an exact upper confidence limit, and the rule-of-three heuristic offers a convenient approximation to that limit for surveys of this size (Hanley and Lippman-Hand, 1983).

When this is done, the result is informative but bounded. The precision achieved is sufficient to render moderate or high seroprevalence in the screened population highly improbable, and this is a substantive finding in its own right. It is not, however, sufficient to satisfy the criterion used in stop-treatment decision-making, which requires the upper confidence limit of Ov16 seroprevalence in children to fall below 0.1 % (WHO, 2016).

A parallel caution applies to the diagnostic platform itself. Ov16 serology detects exposure, not patent infection, and antibody may persist long after the parasite has been cleared; the converse is also true, in that early infection or a weak humoral response may escape detection. Reading time influences RDT interpretation, with some cassettes changing classification beyond the recommended window (Nana-Djeunga *et al.*, 2022), and concordance between RDT and ELISA platforms varies across settings of differing endemicity (Djune-Yemeli *et al.*, 2022; Ekanya *et al.*, 2023). The addition of complementary antigens has been proposed to improve sensitivity (Shintouo *et al.*, 2021), while field evaluations continue to document variation in usability, acceptability and operational performance (Richards *et al.*, 2018; Otobil *et al.*, 2025). None of these considerations invalidates the present finding, but together they explain why a negative serosurvey conducted with a single platform, and without entomological corroboration, cannot on its own verify the absence of transmission.

The Nigerian evidence base makes the argument concrete. Recrudescence of onchocerciasis transmission has been demonstrated in Kaduna State five years after a stop-treatment decision, with infective vector rates exceeding the WHO threshold and seropositive children found in security-compromised communities hosting displaced persons and migrants; insecurity-driven human migration was advanced as a leading candidate driver (Olanrewaju

et al., 2025). Persistence of infection after prolonged MDA has likewise been reported in Enugu, Ogun and Cross River states (Ekpo *et al.*, 2022; Chikezie *et al.*, 2023; Surakat *et al.*, 2023). Elimination is therefore not a uniform or irreversible achievement, and human movement is one of the mechanisms by which hard-won gains can be reversed (Lakwo *et al.*, 2020). Camps such as Wassa sit precisely at the junction of these risks: they receive people from areas of differing endemicity, and they sit within a territory, the FCT, whose river systems have historically supported vector breeding (Crosskey, 1956; Davies, 1968; Post *et al.*, 2011).

It follows that a negative serological screening exercise in a displacement camp should be treated as a baseline entry into a surveillance series rather than as a closed question. The appropriate programmatic response is not reassurance but integration: incorporation of IDP settlements into FCT NTD microplanning, documentation of MDA history at the point of camp registration, repeat screening of children and of newly arrived residents, and coordination with vector control assessment of nearby water bodies. Where resources permit, blackfly collection with molecular xenomonitoring would materially strengthen the evidence base, since modern quantitative polymerase chain reaction assays detect residual transmission that older methods miss (Doherty *et al.*, 2023; Adeleke *et al.*, 2024). Because camp-based outreach already assembles a population at a single point, such screening is also an efficient platform for integrating other NTDs and for delivering complementary vector control measures of demonstrated effectiveness, such as community-driven vegetation clearance at breeding sites (Smith *et al.*, 2019; Raimon *et al.*, 2021), consistent with the cross-cutting, country-owned approach of the current road map (WHO, 2021; WHO, 2024).

CONCLUSION

Ov16 IgG4 rapid diagnostic testing of residents of Wassa IDP Camp, Federal Capital Territory, detected no serological evidence of *Onchocerca volvulus* exposure at the time of screening. The precision achieved is sufficient to make moderate or high seroprevalence highly improbable in the population screened, and the finding is strengthened by the substantial representation of sentinel-age children and the result constitutes a useful baseline for continuing surveillance rather than evidence that the camp population is free of onchocerciasis risk.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

Josephine Alex-Abedo conceptualised and designed the study, supervised field implementation and drafted the manuscript. Eyitope M. Gordon., Rufai S. Abutu and Augustine Agbo. Conducted field screening, data collection and interpretation Mariam. A. Kassim and Sarah I. Bala performed data curation and validation. Faiza Musa collected coordinates and designed the map. All authors reviewed, revised and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

REFERENCES

Adeleke, M.A., Opara, K.N., Mafuyai, H.B., Nwoke, B.E.B., Surakat, O.A., Akinde, S.B. (2024). Improving onchocerciasis elimination surveillance: trials of odour baited Esperanza Window Traps to collect black fly vectors and real-time qPCR detection of *Onchocerca volvulus* in black fly pools. *Parasites & Vectors*, 17(1):471.

Bestwick, C., Badia-Rius, X., Lopes, S., Kelly-Hope, L.A. and Harding-Esch, E.M. (2026). Neglected tropical diseases in conflict-related humanitarian emergency settings: a systematic review of the literature. *International Health*, 18(3):328.

Chikezie, F.M., Opara, K.N., Ubulom, P.M.E., Yaro, C.A., Al-Akeel, R.K., Osei-Atweneboana, M.Y. (2023). Onchocerciasis transmission status in some endemic communities of Cross River State, Nigeria after two decades of mass drug administration with ivermectin. *Scientific Reports*, 13(1):5413.

Clopper, C.J. and Pearson, E.S. (1934). The use of confidence or fiducial limits illustrated in the case of the binomial. *Biometrika*, 26(4):404–413.

Crosskey, R.W. (1956). The distribution of *Simulium damnosum* Theobald in Northern Nigeria. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 50(4):379–392.

Davies, J.B. (1968). The *Simulium* control scheme at Abuja, Northern Nigeria, and its effect on the prevalence of onchocerciasis in the area. *Bulletin of the World Health Organization*, 39(2):187–207.

Djune-Yemeli, L., Domché, A., Nana-Djeunga, H.C., Donfo-Azafack, C., Lenou-Nanga, C.G., Masumbe-Netongo, P. and Kamgno, J. (2022). Relationship between skin snip and Ov16 ELISA: two diagnostic tools for onchocerciasis in a focus in Cameroon after two decades of ivermectin-based preventive chemotherapy. *PLOS Neglected Tropical Diseases*, 16(5):e0010380.

Doherty, M., Grant, J.R., Pilotte, N., Bennuru, S., Fischer, K., Fischer, P.U., Lustigman, S., Nutman, T.B., Pfarr, K., Hoerauf, A., Unnasch, T. R., Hassan, H.K., Wanji, S., Lammie, P.J., Ottesen, E., Mackenzie, C. and Steve n A. Williams, S.A. (2023). Optimized strategy for real-time qPCR detection of *Onchocerca volvulus* DNA in pooled *Simulium* sp. blackfly vectors. *PLOS Neglected Tropical Diseases*, 17(12):e0011815.

Ekanya, R., Beng, A. A., Anim M.A., Pangwoh, Y.Z., O. E. Dibando, O. E., Gandjui N. V. T., Takop, N.G., Theobald Mue Nji, T. (2023). Concordance between Ov16 rapid diagnostic test (RDT) and Ov16 enzyme-linked immunosorbent assay (ELISA) for the diagnosis of onchocerciasis in areas of contrasting endemicity in Cameroon. *Parasite Epidemiology and Control*, 21:e00290.

Ekpo, U.F., Eneanya, O.A., Nwankwo, E.N., Soneye, I.Y., Weil, G.J., Fischer, P.U. and Nwaorgu, O.C. (2022). Persistence of onchocerciasis in villages in Enugu and Ogun states in Nigeria following many rounds of mass distribution of ivermectin. *BMC Infectious Diseases*, 22:832.

Hanley, J.A. and Lippman-Hand, A. (1983). If nothing goes wrong, is everything all right? Interpreting zero numerators. *Journal of the American Medical Association*, 249(13):1743–1745.

International Organization for Migration (2023). *Displacement Tracking Matrix: Nigeria north-central and north-west zones displacement report, round 12*. Abuja: IOM Nigeria.

Isiyaku, S., Igbe, M., Madaki, S., Hamill, L.C., Ndongmo, P., Adamani, W., Ramatu A. Abdullahi, R.A., Adeleke M. A., Adeleke, O.B., Nyior, A., Aliyu, A., Ado G. Mohammed, A. G., Davies, E. S., Anyaike, C., Okoronkwo C., Barbre, K. A.,Tasca E., Anagbogu, I. and B. E. B. Nwoke, B.E.B. (2022). The interruption of transmission of onchocerciasis in Kaduna, Kebbi and Zamfara states, Nigeria: another milestone achievement. *International Health*, 14(Suppl 2):ii43-ii54.

Ityonzughul, C., Sallau, A., Miri, E., Emukah, E., Kahansim, B., Adelamo, S. George, Chiedo G., Ifeanyichukwu, S., Coalson, J. E., Rakers, L., Griswold, E., Makata, C., Oyediran, F., Osuji S., Offor S., Obikwelu E., Otiji, I., Richards F. O.,

- Gregory S. and Noland G.S. (2024). The interruption of transmission of onchocerciasis in Abia, Anambra, Enugu, and Imo states, Nigeria: the largest global onchocerciasis stop-treatment decision to date. *Pathogens*, 13(8):671.
- Lakwo, T., Oguttu, D., Ukety, T., Post, R. and Bakajika, D. (2020). Onchocerciasis elimination: progress and challenges. *Research and Reports in Tropical Medicine*, 11:81–95.
- Metেকে, S., Stefopoulos, M., Als, D., Gaffey, M., Kamali, M., Siddiqui, F.J., Munyuzangabo, M., Jain, R.P., Shah, S., Radhakrishnan, A., Atallah, A. and Bhutta, Z.A. (2020). Delivering infectious disease interventions to women and children in conflict settings: a systematic review. *BMJ Global Health*, 5(Suppl 1):e001967.
- Miri, E.S., Eigege, A., Kahansim, B., Nwodu, K., Sambo, Y., Mancha, B. *et al.* (2022). Two Nigerian states (Plateau and Nasarawa) have eliminated transmission of human onchocerciasis: a report of post-ivermectin mass drug administration surveillance. *American Journal of Tropical Medicine and Hygiene*, 108(1):37–40.
- Nana-Djeunga, H.C., Sicard, C.M., Mogoung-Wafo, A.E., Chesnais, C.B., Deléglise, H., Touka-Nounkeu, R., Domche, A., Golden, A., Klio, A. D., Nutman, T.B., Boussinesq, M., Kamgno, J., Sébastien D. and Pion, S.D. (2022). Changes in onchocerciasis Ov16 IgG4 rapid diagnostic test results over one-month follow-up: lessons for reading timeframe and decision-making. *American Journal of Tropical Medicine and Hygiene*, 107(3):658–661.
- Olanrewaju, T.O., Enwezor, F.N.C., Lar, L.A., Igbe, M.A., Abdullahi, R.A., Adeleke, M.A. and Elhassan E.O. (2025). Recrudescence of transmission of onchocerciasis in some endemic communities in Kaduna State, Nigeria: what is the way forward? *PLOS Neglected Tropical Diseases*, 19(8):e0012495.
- Otabil, K.B., Basáñez, M.G., Ameyaa, E., Oppong, M., Mensah, P., Gyasi-Ampofo, R., Bart-Plange, E. J., Nti Babae, T., Datsa, L., Boaky, A.A., Yeboah, M.T., Nyarko, P., Kudzordzi, P. C., Acheampong, A., Blay, E.T., Schallig, H.D. and Colebunders R. (2025). Usability, acceptability, and cost of the SD BIOLINE Ov16 rapid diagnostic test for onchocerciasis surveillance in endemic communities in the middle belt of Ghana. *PLOS Neglected Tropical Diseases*, 19(8):e0012191.
- Post, R.J., Onyenwe, E., Somiari, S.A.E., Mafuyai, H.B., Crainey, J.L. and Ubachukwu, P.O. (2011). A guide to the *Simulium damnosum* complex (Diptera: Simuliidae) in Nigeria, with a cytotoxic key for the identification of the sibling species. *Annals of Tropical Medicine and Parasitology*, 105(4):277–297.
- Raimon, S., Lakwo, T.L., Sebit, W.J., Siewe Fodjo, J.N., Alinda, P., Carter, J.Y., Post, R.J. and Robert Colebunders R (2021). "Slash and clear", a community-based vector control method to reduce onchocerciasis transmission by *Simulium sirbanum* in Maridi, South Sudan: a prospective study. *Pathogens*, 10(10):1329.
- Richards, F.O., Katabarwa, M., Bekele, F., Tadesse, Z., Mohammed, A., Sauerbrey, M., Rizzo, N., Zarroug I.M.A., Lovato, E., Zea-Flores, G., Oliva, O., Catú, E., Morales, A.L., Lovato, R., Guevara, A., Ronald Guderian, R. and Unnasch, T. R.. (2018). Operational performance of the *Onchocerca volvulus* "OEPA" Ov16 ELISA serological assay in mapping, guiding decisions to stop mass drug administration, and post-treatment surveillance surveys. *American Journal of Tropical Medicine and Hygiene*, 99(3):749–752.
- Shintouo, C.M., Shey, R. A., Hotterbeekx, A., Yagmur, E., Mets, T., Vanhamme, T., Colebunders, R., Souopgui, J. and Njemini R. (2021). Tandem use of OvMANE1 and Ov-16 ELISA tests increases the sensitivity for the diagnosis of human onchocerciasis. *Life*, 11(12):1284.
- Smith, M.E., Bilal, S., Lakwo, T.L., Habomugisha, P., Tukahebwa, E., Byamukama, E., Katabarwa M. N., Richards, F. O., Cupp, E. W., Unnasch, T. R. and Michael, E. (2019). Accelerating river blindness elimination by supplementing MDA with a vegetation "slash and clear" vector control strategy: a data-driven modeling analysis. *Scientific Reports*, 9(1):15274.
- Surakat, O.A., Babalola, A.S., Adeleke, M.A., Adeogun, A.O., Idowu, O.A. and Sam-Wobo, S.O. (2023). Geospatial distribution and predictive modeling of onchocerciasis in Ogun State, Nigeria. *PLOS ONE*, 18(3):e0281624.
- World Health Organization (2016). *Guidelines for stopping mass drug administration and verifying elimination of human onchocerciasis: criteria and procedures*. Geneva: World Health Organization.
- World Health Organization (2021). *Ending the neglect to attain the Sustainable Development Goals: a road map for neglected tropical diseases 2021–2030*. Geneva: World Health Organization.
- World Health Organization (2024). *Global report on neglected tropical diseases 2024: stronger together, towards 2030*. Geneva: World Health Organization.
- World Health Organization (2025). *Onchocerciasis*. WHO fact sheet. Geneva: World Health Organization.