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PERSISTENCE OF ONCHOCERCIASIS INFECTION AFTER DECADES OF MASS DRUG ADMINISTRATION IN THE WESTERN NORTH REGION OF GHANA

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ABSTRACT

Introduction

Onchocerciasis, a neglected tropical disease caused by Onchocerca volvulus, remains a significant public health concern in endemic regions despite decades of mass drug administration (MDA) with ivermectin (IVM). This study evaluates the impact of IVM MDA on onchocerciasis transmission in the Sefwi Akontombra district of Ghana and identifies factors contributing to the persistence of the infection.

Methodology

A cross-sectional study was conducted across 25 communities in the district. Participants were clinically examined for palpable onchocercomata, and compliance with IVM treatment was assessed through structured interviews and community health records. Participants with one or more palpable sub-cutaneous nodule had skin snips taken from the iliac crests for microfilariae assessment. Data were analysed using descriptive statistics, chi-square tests, and logistic regression models.

Results
Of the 1,980 participants assessed, 35.4% had subcutaneous nodules, with variations in prevalence across communities. The district community microfilariae load (CMFL) and geometric mean intensity were 0.25 MF/ss and 0.26 MF/ss respectively. Age, MDA compliance and gender were the independent predictive factors significantly associated with onchocerciasis in the district.
Conclusion
While MDA has reduced onchocerciasis prevalence, transmission persists. To accelerate elimination efforts, targeted interventions should focus on increasing MDA compliance through intensified community engagement, integrating alternative treatment strategies such as anti-Wolbachia therapy, and adopting more sensitive diagnostic tools for improved surveillance.
Keywords: Onchocerciasis, Microfilaria, mass drug administration, Ivermectin, Ghana.

INTRODUCTION

Onchocerciasis, commonly known as river blindness, is a parasitic disease caused by *Onchocerca volvulus*, transmitted through repeated bites of infected blackflies (*Simulium spp.*) that breed in fast-flowing rivers and streams near fertile agricultural lands (Shintouo *et al.*, 2020; Tsapi *et al.*, 2020). The disease leads to severe skin conditions, vision impairment, and in extreme cases, blindness. It affects millions globally, with over 99% of cases occurring in Africa, including Ghana (World Health Organisation, 2022). The disease manifests as intense pruritus, acute and chronic papular onchodermatitis, loss of skin elasticity, and depigmentation, significantly impacting the quality of life and productivity of affected individuals (Okulicz *et al.*, 2018; World Health Organisation, 2022). Control efforts for onchocerciasis have evolved over decades, primarily through the Onchocerciasis Control Programme (OCP) (1974–2002) and the African Programme for Onchocerciasis Control (APOC) (1995–2015). These programs employed vector control measures and mass drug administration (MDA) with ivermectin (IVM), leading to substantial reductions in disease burden (Biritwum *et al.*, 2021). However, despite nearly three decades of MDA in endemic regions like Ghana, the persistence of the disease remains a public health challenge (Katabarwa *et al.*, 2013; Biritwum *et al.*, 2021).

In Ghana, MDA with IVM was introduced in 1994 as part of APOC's community-directed treatment initiative, with biannual treatment commencing in 2018 (Biritwum *et al.*, 2021). The intervention significantly reduced the prevalence of *O. volvulus* microfilariae (MF) and community microfilarial load (CMFL), improving disease control efforts. However, studies have shown that MDA effectiveness is influenced by compliance levels, the longevity of adult worms, and the potential emergence of IVM resistance (Awadzi *et al.*, 2004a, 2004b; Osei-Atweneboana *et al.*, 2011; Arndts *et al.*, 2014). Some studies report persistent MF prevalence despite multiple rounds of IVM administration, suggesting suboptimal efficacy or resistance in certain populations (Awadzi *et al.*, 2004a, 2004b; Osei-Atweneboana *et al.*, 2011). More recent reports indicate a decline in onchocerciasis prevalence in Ghana, with reductions from 69.13% in 1975 to 0.72% in 2015, and CMFL dropping from 14.48 MF/skin snip to 0.07 MF/

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skin snip over the same period (Biritwum *et al.*, 2021). Despite these gains, some regions, including the Western North Region, continue to report cases, underscoring the need for further investigations into the persistence of the infection. The Sefwi Akontombra district, formerly part of the Sefwi Wiawso district, has been endemic for onchocerciasis, with historical MF prevalence ranging between 35% and 60% before MDA initiation (Biritwum *et al.*, 2021). The district has implemented IVM treatment for nearly three decades, with reported MDA compliance averaging 85% over 15 years. However, current data on the prevalence and transmission dynamics of onchocerciasis in this region remain limited and outdated, necessitating renewed research efforts. The COVID-19 pandemic disrupted MDA programs worldwide, including Ghana, where MDA was halted in 2020 following WHO recommendations (Hamley *et al.*, 2021). This disruption may have contributed to continued disease transmission, emphasising the need for updated epidemiological assessments. Understanding the factors contributing to onchocerciasis persistence is crucial for refining elimination strategies and achieving WHO's 2030 elimination goals (World Health Organisation, 2020).

This study aims to assess the current MF and nodule prevalence of onchocerciasis in the Sefwi Akontombra district and investigate factors contributing to its persistence. Specifically, it seeks to determine the effectiveness of IVM-based MDA in interrupting transmission, evaluate compliance patterns, and identify potential gaps in disease control. The findings will provide critical insights into the ongoing transmission of onchocerciasis in the region and inform strategic interventions for accelerating elimination efforts. Despite significant progress in onchocerciasis control, achieving elimination remains a challenge in certain endemic areas. While MDA has been pivotal in reducing disease burden, persistent transmission in some districts suggests that additional measures, including intensified MDA, enhanced community engagement, and alternative treatment strategies, may be necessary (WHO, 2010; Batsa Debrah *et al.*, 2020). Research into new or repurposed anti-filarial agents, such as macrofilaricidal drugs targeting adult worms, could complement existing interventions and improve elimination outcomes. Our ongoing trial on alternative treatment strategies using anti-Wolbachia drugs aims to explore new therapeutic options to accelerate onchocerciasis elimination. In summary, this study addresses the gap in onchocerciasis surveillance in the Sefwi Akontombra district after decades of MDA. By assessing the current disease burden and identifying persistence factors, the findings will contribute to refining control strategies and advancing Ghana's onchocerciasis elimination agenda.

MATERIALS AND METHODS

Ethics statement and approvals

This study was approved by the Committee on Human Research, Publication and Ethics (CHRPE) of the School of Medicine and Dentistry of the Kwame Nkrumah University of Science and Technology, KNUST, Kumasi, Ghana. Community leaders were consulted at the beginning of the study for their support and permission, and written approval was sought from the Western North Regional and the Sefwi Akontombra District Health Directorates. Written informed consent was voluntarily sought from all participants either by thumbprinting or signing before being enrolled in the study. Assents were completed for participants who were under 18 years (minors), with parents/legal guardians giving formal written consent for such volunteers/participants. The study followed the Helsinki Declaration (1964, amended 2013). This study is part of a larger ongoing trial: "Alternative treatment strategies using anti-Wolbachial drugs to accelerate elimination of Lymphatic Filariasis and Onchocerciasis (ASTAWOL) – sponsored by the European and Developing Countries Clinical Trial Partnership (EDCTP 2). The ethical approval number/code for the study is CHRPE/AP/337/20.

Study area/setting, site and population

The study was carried out in the Sefwi Akontombra district in the Western North Region (a newly created Region carved out of the then Western Region) of Ghana. Ghana on 27th December, 2018 held a referendum which led to the creation of 6 more regions in addition to the 10 that already existed. This, in consequence led to the creation of the Western North Region out of the Western Region (The Permanent Mission of Ghana to the United Nations, 2021). The Sefwi Akontombra District is located in the northeastern part of Ghana's Western Region. It lies between latitudes 6° and 6°30' North, and longitudes 2°15' and 2°45' West. The district is bordered to the north by the Sefwi Wiawso and Juabeso Districts, to the southeast by Aowin Suaman, and to the southwest by Wassa Amenfi (Nartey *et al*., 2023). Sefwi Akontombra District is located in Ghana and is characterised by a landscape dissected by rivers and a clay surface, which makes many roads muddy and slippery during the rainy season and dusty during the dry season. This geography presents a challenge to transportation and accessibility, especially in rural and agricultural areas.

The district has a population of 70,225, comprising 36,918 males and 33,307 females. The district experiences a heavy annual rainfall pattern, significantly impacting infrastructure maintenance and transportation, particularly during the rainy season. Economically, Sefwi Akontombra is predominantly agrarian, with agriculture employing about 84% of the workforce. Major crops include cocoa, oil palm, plantain, cocoyam, cassava, maize, and rice, alongside various fruits and vegetables. The district produces nearly 6,000 metric tons of cocoa annually and has significant potential for agro-processing, though industrial development remains limited. The area is also rich in natural resources, with three forest reserves, valuable timber species, and gold deposits, particularly in Akontombra and along the Tano River (Ministry of Finance, 2023, 2025).

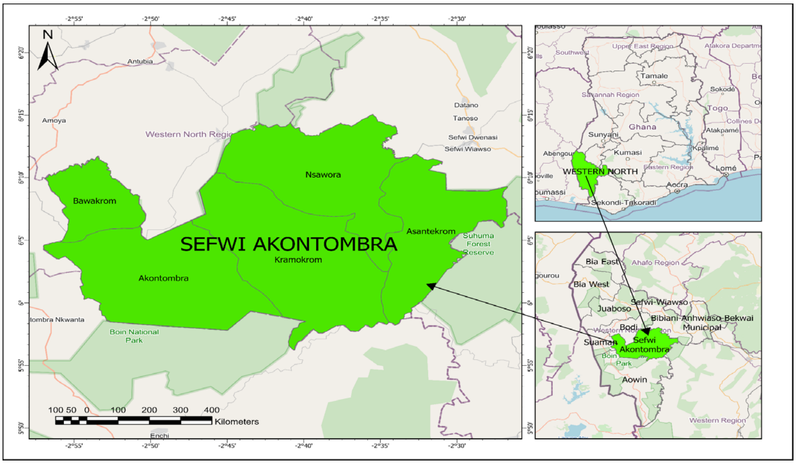

Fig. 1: Map of study area (created with ESRI ArcGIS Pro 3.1.0)

Status of MDA in Sefwi Akontombra District

The Sefwi Akontombra district, formerly part of the Sefwi Wiawso district (in the Western Region) was mesoendemic for onchocerciasis in 1980, with MF prevalence of 35%-60% before MDA with IVM begun (Biritwum *et al.*, 2021). The district during the time of recruitment had administered ivermectin treatment for the interruption of infection transmission in all surveyed communities for close to three decades since MDA began in the district. The last MDA prior to recruitment was carried out in May 2019. Annual MDA is reported to have begun in the district in the year 1994 and biannual treatment since 2018 as indicated by the district disease control office. From the community MDA registers and according to the district disease control office, there was an average MDA compliance of 85% for over 15 years. This study is the first to assess the impact of IVM MDA on Onchocerciasis infection in the Western North region of Ghana after decades of its administration.

STUDY DESIGN AND RECRUITMENT

This study used a population-based cross-sectional study design that employed a purposive selection of motorable study communities and a convenience sampling approach for recruitment of potential participants. Recruitment of study participants took place directly in the communities from November 2020 to April 2021, through a voluntary participation without an epidemiologically pre-defined sample size being determined. Before recruitment commenced, information was sent to the participating communities through information centres and also by the community health volunteers (CHV). A formal meeting was later held with community leaders and interested community members to explain the details of the study to them and questions appropriately addressed in both English, Twi and Sefwi (local language used by the people) languages as preferred by the participants. On the day of recruitment, informed consent forms were administered to those who were interested and willing to participate in the study. This was done in their local languages (Sefwi and Twi), as well as in English. Willing participants were asked to sign or thumbprint an informed consent form. Any individual over the age of 18 who has lived in the endemic community for two or more years and is mentally sound enough to give consent (for adults) or consent on behalf of their wards (minors; <18 years) as parents or legal guardians was deemed fit for inclusion. The exclusion criteria included any individual <5 years who had stayed in the endemic community for <2 years,was not mentally sound and was not ready to give consent. A total of 2,019 participants from 25 communities in three sub-districts (Asantekrom, Kramokrom and Nsawora), all under the Sefwi Akontombra district were consented and enrolled on the study. These 2,019 participants were enrolled based on voluntary participation in the study and not on an epidemiologically pre-defined sample size. An approved short-structured interview forms were used to collect demographics such as sex, age, number of rounds of IVM MDA treatment and number of years lived in the endemic area. This was assessed through participant interviewing, with interviews structured according to a predefined questionnaire which was administered by the investigators (research team) at a place far from the gathering, with participants assured of data safety and confidentiality of their responses (Adu Mensah *et al*., 2022). To prevent MDA treatment round recall bias, responses from participants were re-checked/cross-checked from the last fifteen (15) MDA treatment records with the CHVs in the communities who have the MDA records for every household. This was done before the numbers were used in any analyses (Adu Mensah *et al*., 2022). Individuals enrolled were given unique personal identification numbers for data collection, processing and laboratory results. Participants were then palpated and those with one or more palpable sub-cutaneous nodules had skin biopsies taken (snipped) from the left and right iliac crests for later parasitological assessment.

Palpation for Onchocercomata

Participants were physically examined and palpated by trained and experienced research scientists following standard procedures for the presence of onchocerciasis nodules (onchocercomata/sub-cutaneous nodules). The presence, size, number and site of onchocercomata identified were documented on a well-structured case report form. Nodules vary in size and the distinguishable features from other non-onchocerciasis nodules are that they are usually firm to touch, often flattened, bean-shaped, movable and non-tender. The presence of nodules likely suggests the existence of adult worms of *O. volvulus* (Hofman, 2016). Such participants were snipped for MF assessment.

Parasitological assessment (skin snipping and microscopy)

Skin snips (biopsies) were taken from the left and right superior iliac crests from only nodule-positive individuals using a 2mm Holth corneoscleral punch. After taking a biopsy from a participant, the corneoscleral punch was immersed in a disinfectant for 15-20 minutes and then sterilised in an autoclave at 121^{o}C for 15 minutes before being used again. For every individual, two (2) bloodless snips (left and right) of 5-10 mg skin were taken to determine microfilarial loads after both sides of the iliac crest of each person were disinfected with cotton wool soaked in 70% ethanol. Briefly, the skin biopsies were immersed and incubated in 1000 µL of 0.9% physiological saline (sodium chloride) in a 24-well microtiter plate overnight for the emergence of MF from the skin. These were examined with an inverted microscope by two independent, experienced microscopists, and the number of *O. volvulus* MF (differentiated from other filarial skin MFs such as *O. ochengi* and *M. streptocerca* by morphological features) from both left and right snips was counted. The 2 biopsies were then measured with an electronic mass balance and the arithmetic mean densities (load) of MF per mg of skin (left and right) for every individual were determined. The wounds from the sites where the skin biopsies were taken were covered with a phlebotomy spot plaster to help avoid infection. Participants were advised to keep the area clean until the wound had healed (Awadzi *et al.*, 2004; Osei-Atweneboana *et al.*, 2011).

Physical examinations for dermal Onchocerciasis

The study participants were further examined for signs of dermal/skin onchocerciasis, and the results of these assessments were recorded in case report forms designed for the prevalence assessment. Dermal onchocerciasis, defined as any of the common skin manifestations of onchocerciasis such as lymphadenopathy, hanging groin, acute/chronic papular onchodermatitis, lichenified onchodermatitis, atrophic skin, depigmentation (leopard skin) and sowda (severe itching and skin darkening often confined to one limb) (Noormahomed et al., 2016; Okulicz et al., 2018), were assessed during participant recruitment and findings recorded.

Parasitological indices/ Analysis plan

Nodule and MF prevalence assessment expressed as percentages were used to determine the degree of endemicity of onchocerciasis. Data for each community was expressed as the geometric mean intensities from all skin snipped individuals (both MF positives and negatives) using the antilogarithm of $[(\Sigma\log(x+1))/n]-1$, where 'x' is the arithmetic mean of MF/mg of skin and 'n' being the number of participants assessed (Debrah *et al*., 2006). Community Microfilarial Load (CMFL), the true reflection of the measure of the onchocerciasis infection intensity by considering individuals aged 20 years and above was also calculated as microfilariae per skin snip (MF/ss) (including MF counts of zero) using the adjusted geometric mean as the reference index of the infection intensity (Remme *et al*., 1986; Osei-Atweneboana *et al*., 2007).

Statistical analysis

Pearson's Chi-square analysis was used to test for the association between demographic factors and infection status (nodule and MF). Independent variables were analysed using bivariate and multivariate logistic regression models (Crude and Adjusted odds ratio) to identify risk factors significantly associated with nodule and MF prevalence at a confidence level of 95%. Parameters that were significant in the bivariate regression analyses were adjusted for the multivariate regression modelling. Differences between independent continuous variables were assessed with the Mann-Whitney U test. Statistical significance was considered at $p\text{-value} < 0.05$. Data were captured using Microsoft Excel 2019. All analyses were done using SPSS version 25 and GraphPad Prism 9 for graphing data. All reported prevalences are estimates based on the voluntary participation in the study and not an epidemiologically defined sample size.

RESULTS

Demographic distribution

A total of 2,019 participants were examined from 25 study communities in the Sefwi Akontombra district of Ghana. However, 1980 participants (98.1%) were used in the analysis (and 39 were excluded) due to incomplete data and/or inconsistencies/non-agreement in participants' MDA treatment record responses as compared to the CHVs MDA register for every household. The 1980 participants had a mean age of 38.7 (±13.4) years, with more than half (999, 50.5%) being females with the majority in the age bracket of 34–44 years [Table I]. The participants had lived in the study district for an average of 24.5 (±12.9) years [Table I].

Table I: Distribution of age and gender among study participants in the Sefwi Akontombra district.

Variable	Mean	Standard Deviation (±SD)	
Age (years)	38.7	13.4	
Years lived in endemic area	24.5	12.9	
Age Groups		**Gender**	
	Male, *N* (%)	Female, *N* (%)	Total, *N* (%)
12-22	137 (45.2)	166 (54.8)	303 (100)
23-33	178 (45.1)	217 (54.9)	395 (100)
34-44	280 (48.0)	303 (52.0)	583 (100)
45-55	290 (55.1)	236 (44.9)	526 (100)
≥56	96 (55.5)	77 (44.5)	173 (100)
Total	**981 (49.5)**	**999 (50.5)**	**1980 (100)**

N; **number of cases examined**

Distribution of nodules and MF among study participants

The overall palpable nodule prevalence from the study district was 35.4% (N = 701), out of which 31.5% (N = 221) were MF positive. More males, 447 (45.6%) had Onchocerca subcutaneous nodules as compared to females; 254 (25.4%). This observation was also the same for MF prevalence among nodule positives in the study district (35.1% vs 25.2%) [Table II]. Regarding the distribution of nodule status among age groups of participants, nodule prevalence was least among the 12—22-year age group (17.2%) and was significantly associated with the participants' age (p<0.001).

Notably, the highest MF prevalence among nodule positives was recorded among the 12–22-year age group (46.2%), with MF positivity significantly associated with age (p=0.015) [Table II]. Nodule positive participants were older as compared to the nodule negative participants (p<0.001); however, the reverse was observed regarding MF status (p<0.001) [Fig. 2].

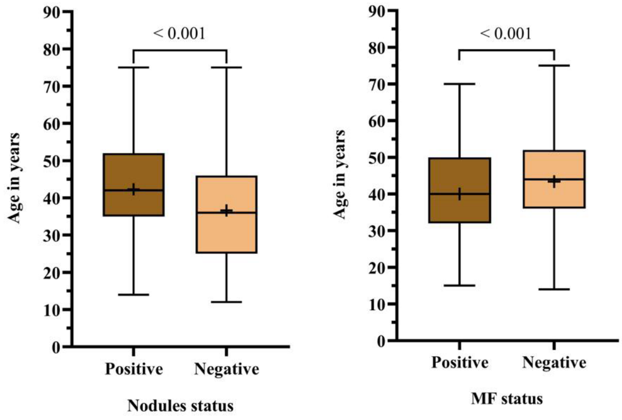

Fig. 2: Age distribution among Onchocerca nodules and MF status

Nodule and MF positivity were highest in males and in the age groups of 45 – 55 and 12 -22-years respectively [Fig. 3].

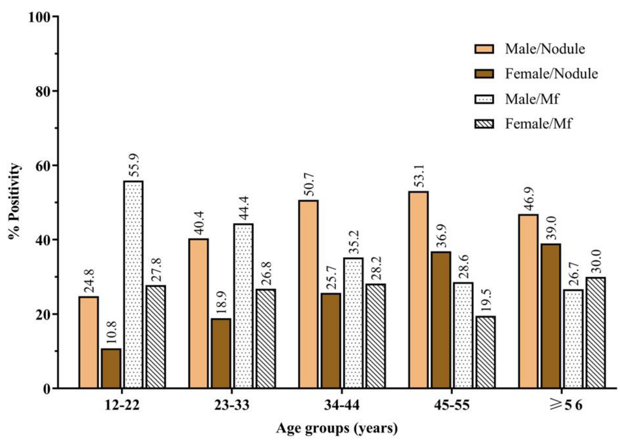

Fig. 3: Distribution of Onchocerca nodules and MF among age groups and gender

More than half of the participants (53.6%, N = 1062) had lived in the endemic area for ≥ 20 years, out of which 419 (39.5%) were nodule positive, with 126 (30.1%) being microfilaridermic [Table II]. Significant association was found between the number of years participants had lived in the endemic area and the acquisition of Onchocerca nodules ($p<0.001$). However, this was not the case for MF positivity ($p=0.312$) [Table II].

Table II: Demographic characteristics of nodule and microfilarial status of the study participants in Sefwi Akontombra district.

			Nodule Status			**Microfilaria (MF) Status**		
Variable	**Category**	**Cases**	**Positive(%)**	**Negative(%)**	**P-value**	**Positive (%)**	**Negative(%)**	**P-value**
Gender[a]	Male	981 (49.5)	447 (45.6)	534 (54.4)	<0.001	157 (35.1)	290 (64.9)	0.007
	Female	999 (50.5)	254 (25.4)	745 (74.6)		64 (25.2)	190 (74.8)	
Age (years)[a]	12 – 22	303 (15.3)	52 (17.2)	251 (82.8)	<0.001	24 (46.2)	28 (53.8)	0.015
	23 – 33	395 (19.9)	113 (28.6)	282 (71.4)		43 (38.1)	70 (61.9)	
	34-44	583 (29.4)	220 (37.7)	363 (62.3)		72 (32.7)	148 (67.3)	
	45-55	526 (26.6)	241 (45.8)	285 (54.2)		61 (25.3)	180 (74.7)	
	≥56	173 (8.7)	75 (43.4)	98 (56.6)		21 (28.0)	54 (72.0)	
Years lived in endemic area[a]	< 20 yrs.	918 (46.4)	282 (30.7)	636 (69.3)	<0.001	95 (33.7)	187 (66.3)	0.312
	≥ 20 yrs.	1,062 (53.6)	419 (39.5)	643 (60.5)		126 (30.1)	293 (69.9)	
		1980 (100)	**701 (35.4)**	**1279 (64.6)**		**221 (31.51)**	**480 (68.5)**	

[a]Pearson Chi-square test; [1], Onchocerciasis prevalence based on only nodule positive participants

Averagely, MF was more prevalent among participants with more nodules and this differed significantly from the MF negative group (p<0.001) [Fig. 4].

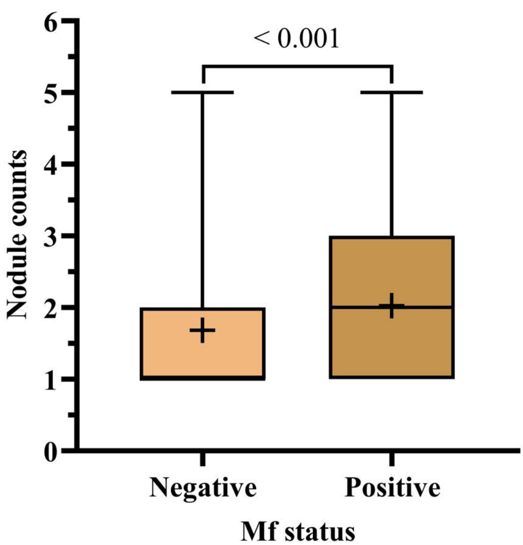

Fig. 4: Onchocerca nodule count distribution against MF status

Palpable *Onchocerca* nodules were present among participants from all communities surveyed [Table III]. Kwaku-Ofori (83.3%) and Nyamebekyere (50.0%) communities recorded the highest nodule and MF prevalences respectively. Measurement of community onchocerciasis endemicity based on MF prevalence revealed that fourteen (14) communities were hypoendemic (<35%), with eleven (11) being mesoendemic (35% – 60%) for onchocerciasis. Findings from the current study showed that the study district, Sefwi Akontombra is hypoendemic for the onchocerciasis disease, and also had a geometric mean (GM) intensity of 0.26 MF/ss. Adawu (0.77 MF/ss) and Bopa-Nkwanta (0.02 MF/ss) communities recorded the highest and least GM/CMFL respectively. The district's CMFL was shown to be 0.25 MF/ss [Table III].

Table III: Community prevalence and Onchocerciasis status in the Sefwi Akontombra district.

Community	Cases	Nodule Positive N (%)	MF Positive N (%)	GM intensity MF/ss	CMFL MF/ss	IVM (MDA) intake N (%)	Rounds of MDA, Median (Min-Max)
Adawu[1]	37	15 (40.5)	7 (46.7)	0.77	0.77	33 (89.2)	3 (0-4)
Amanfokrom[1]	51	17 (33.3)	8 (47.1)	0.39	0.39	39 (76.5)	3 (0-5)
Aprogya[2]	57	14 (25.6)	2 (14.3)	0.05	0.05	55 (96.5)	3 (0-5)
Asamoakrom[2]	34	14 (41.2)	3 (21.4)	0.07	0.06	27 (79.4)	4 (3-7)
Asamoano[2]	71	20 (28.2)	3 (15.0)	0.12	0.13	68 (95.8)	4 (2-7)
Asantekrom[2]	196	44 (22.4)	14 (31.8)	0.26	0.24	190 (96.9)	4 (1-7)
Asiekrom[2]	102	18 (17.6)	3 (16.7)	0.10	0.10	96 (94.1)	4 (0-8)
Bopa[2]	112	52 (46.4)	10 (19.2)	0.17	0.17	108 (96.4)	4 (1-8)
Bopa-Nkwanta[2]	36	10 (27.8)	2 (20.0)	0.02	0.02	27 (75.0)	3 (0-5)
Congo-Kusikrom[1]	107	43 (40.2)	21 (48.8)	0.48	0.41	99 (92.5)	3 (1-6)
Kofikrom[2]	108	37 (34.3)	9 (24.3)	0.08	0.08	106 (98.1)	4 (1-6)
Kojobikrom[1]	98	41 (41.8)	18 (43.9)	0.40	0.40	95 (96.9)	3 (0-8)
Kwaku-Ofori[1]	12	10 (83.3)	4 (40.0)	0.26	0.26	12 (100.0)	4 (1-5)
Mafiedu[1]	62	28 (45.2)	11 (39.3)	0.32	0.32	57 (91.9)	4 (1-8)
Mampong[2]	94	24 (25.5)	3 (12.5)	0.07	0.07	94 (100.0)	4 (1-6)
Manukrom[1]	99	44 (44.4)	17 (38.6)	0.28	0.28	95 (96.0)	4 (1-8)
Mensakrom[1]	57	23 (40.4)	8 (34.8)	0.17	0.10	54 (94.7)	3 (0-6)
Ntom[2]	87	23 (26.4)	5 (21.7)	0.11	0.04	76 (87.4)	5 (1-10)
Nyamebekyere[1]	26	18 (69.2)	9 (50.0)	0.47	0.47	23 (88.5)	4 (2-6)
Nyamendae[2]	70	42 (60.0)	10 (23.8)	0.28	0.28	63 (90.0)	4 (0-8)

Obengkrom[1]	136	41 (30.1)	19 (46.3)	0.47	0.49	127 (93.4)	4 (1-10)
Oppongkrom[1]	53	22 (41.5)	9 (40.9)	0.25	0.25	50 (94.3)	4 (0-6)
Shed[2]	82	27 (32.9)	7 (25.9)	0.27	0.17	80 (97.6)	5 (1-8)
Sunkwa[2]	31	15 (48.4)	4 (26.7)	0.26	0.26	27 (87.0)	4 (1-5)
Wuruwuru[2]	162	59 (36.4)	15 (25.4)	0.22	0.23	155 (95.7)	4 (1-7)
Total	**1980**	**701 (35.4)**	**221 (31.5)**	**0.26**	0.25	1856 (93.7)	5 (0-10)

[1], Mesoendemic communities; [2], Hypoendemic communities; N, number of participants examined; MF, Microfilaria; GM, Geometric mean; CMFL, Community microfilarial load; IVM, Ivermectin; MDA, Mass Drug Administration; MF/ss, Microfilaria per skin snip

Most of the participating communities (16) had a median IVM round of four as reported by the participants, with two (2) others having just five rounds as the maximum partaken MDA treatment by participants [Table III]. With regards to community-based IVM compliance; two communities, Kwaku-Ofori and Mampong had all participants (100%) taking IVM ≥1 in the past. However, Bopa-Nkwanta had the least (75.0%) compliance to MDA among the study communities [Table III].

Distribution of dermal Onchocerciasis among study participants

From the 1,980 study participants examined, only 17 (0.9%) who were all microfilaridermic exhibited some forms of dermal/skin manifestations of onchocerciasis. Of the 17 participants, seven (41.2%) had developed acute papular onchodermatitis, whiles five each (29.4%) had atrophic skin and sowda. None of the 17 participants exhibited two or more conditions of the dermal onchocerciasis. Assessment of visual impairment/ocular defects due to onchocerciasis was not done.

Compliance of participants with Ivermectin (IVM) MDA treatment

All study communities reported having MDA with IVM implemented and being carried out in their communities. The participants reported receiving the yearly IVM treatment through the CHVs for ≥20 rounds. The overall compliance level of the Sefwi Akontombra district regarding treatment with IVM in response to MDA intervention was high, with 93.7% (N=1856) of the participants having taken IVM at least once in ≥20 MDA rounds.

Compliance by gender

The participants recorded an average IVM MDA of 5 (0 – 10) times over the past ≥20 years, with compliance among genders showing that both males and females equally adhered to MDA (50.0%). Further to this, 7.1% (N=71) of females and 5.4% (N=53) of males had never taken IVM in the past, 81.0% (N=809) and 80.6% (N=791) of all females and males respectively had taken it at least once (1 – 5) and 11.9% (N=119) of females and 14.0% (N=137) of males had taken >5 rounds over the past ≥20. Nevertheless, there was no significant association between gender and IVM compliance nor the number of rounds taken (p=0.118 and 0.141 respectively).

Table IV: Compliance of participants to Ivermectin treatment in Sefwi Akontombra district

Variable	Category	Cases (%)	IVM intake (MDA)			Number of IVM rounds taken (MDA)			
			Compliance	Non-compliance	p-value	0	1-5	>5	p-value
Gender[a]	Male	981 (49.5)	928 (94.6)	53 (5.4)	0.118	53 (5.4)	791 (80.6)	137 (14.0)	0.141
	Female	999 (50.5)	928 (92.9)	71 (7.1)		71 (7.1)	809 (81.0)	119 (11.9)	
Age[a]	12-22	303 (15.3)	267 (88.1)	36 (11.9)	< 0.001	36 (11.9)	265 (87.5)	2 (0.7)	< 0.001
	23-33	395 (19.9)	349 (88.4)	46 (11.6)		46 (11.6)	340 (86.1)	9 (2.3)	
	34-44	583 (29.4)	553 (94.9)	30 (5.1)		30 (5.1)	487 (83.5)	66 (11.3)	
	45-55	526 (26.6)	517 (98.3)	9 (1.7)		9 (1.7)	412 (78.3)	105 (20.0)	
	≥56	173 (8.7)	170 (98.3)	3 (1.7)		3 (1.7)	96 (55.5)	74 (42.8)	
Years lived in endemic area[a]	<20 yrs.	918 (46.4)	821 (89.4)	97 (10.6)	< 0.001	97 (10.6)	736 (80.2)	85 (9.3)	< 0.001
	≥ 20 yrs.	1,062 (53.6)	1035 (97.5)	27 (2.5)		27 (2.5)	864 (81.4)	171 (16.1)	
Total		**1980 (100)**	**1856 (93.7)**	**124 (6.3)**		**124 (6.3)**	**1600 (80.8)**	**256 (12.9)**	

[a]Pearson Chi-Square; MDA, Mass Drug Administration; IVM, Ivermectin

Compliance by age

The 45-55 and ≥56-year age groups were the most compliant (98.3%) over the ≥20 years of IVM MDA treatment, with the compliance rate being significantly associated with age (p<0.001). Individuals who had lived in the endemic communities for ≥20 years showed a greater degree of MDA compliance, with 97.5% (N=1035) having taken MDA ≥1 and 81.4% (N=864) participating in 1 – 5 treatment rounds [Table IV]. Though majority (93.7%) of the participants had taken IVM ≥1, only 12.9% had taken >5 rounds albeit having stayed in the filarial endemic area for an average of 24.5 (±12.9) years. Thus, as the treatment rounds increased, participation in the MDA program reduced.

Reasons cited by participants for IVM MDA non-compliance

The study also revealed that 6.3% (N=124) of the participants had never taken part in MDA for a number of reasons [Table IV], with 33(26.6%) being nodule positives. Out of the 33 nodule positives, 17 (51.5%) were microfilaria positives [Tables V and VI].

Table V: Analyses of independent predictors associated with *Onchocerca* nodules in the Sefwi Akontombra district.

Variable	Category	Cases (%)	Nodule Status		COR [95% CI]	p-value	AOR [95% CI]	p-value
			Positive (%)	Negative (%)				
Gender	Male	981 (49.5)	447 (45.6)	534 (54.4)	2.455 [2.031-2.969]	< 0.001*	2.388 [1.967-2.898]	< 0.001*
	Female	999 (50.5)	254 (25.4)	745 (74.6)	1.000		1.000	
Age (years)	12-22	303 (15.3)	52 (17.2)	251 (82.8)	1.000		1.000	

	23-33	395 (19.9)	113 (28.6)	282 (71.4)	1.934 [1.226-2.800]	< 0.001*	1.961 [1.340-2.869]	0.001*
	34-44	583 (29.4)	220 (37.7)	363 (62.3)	2.925 [2.0771-4.120]	< 0.001*	2.874 [2.000-4.131]	< 0.001*
	45-55	526 (26.6)	241 (45.8)	285 (54.2)	4.082 [2.893-5.760]	< 0.001*	3.758 [2.583-5.467]	< 0.001*
	≥ 56	173 (8.7)	75 (43.4)	98 (56.6)	3.694 [2.418-5.644]	< 0.001*	3.258 [2.032-5.224]	< 0.001*
Years lived in endemic area	<20 yrs	918 (46.4)	282 (30.7)	636 (69.3)	1.000		1.000	
	≥20 yrs	1,062 (53.6)	419 (39.5)	643 (60.5)	1.470 [1.220-1.771]	< 0.001*	1.023 [0.828-1.263]	0.835
IVM intake (MDA)	Compliance	1856 (93.7)	668 (36.0)	1188 (64.0)	1.000		1.000	
	Non-Complaince	124 (6.3)	33 (26.6)	91 (73.4)	0.645 [0.428-0.971]	0.036*	0.802 [0.483-1.332]	0.393
Number of rounds of IVM intake (MDA)	0	124 (6.3)	33 (26.6)	91 (73.4)	1.000		1.000	
	1-5	1600 (80.8)	553 (34.6)	1047 (65.4)	1.456 [0.965-2.198]	0.073	0.865 [0.647-1.156]	0.328
	>5	256 (12.9)	115 (44.9)	141 (55.1)	2.249 [1.408-3.592]	0.001*	-	-

***, Statistically significant p-values (p < 0.05); COR, Crude Odds Ratio; AOR, Adjusted Odds Ratio; CI, Confidence interval**

Table VI: Analyses of independent predictors associated with onchocerciasis microfilaria in the Sefwi Akontombra district.

Variable	**Category**	**Cases (%)**	**Microfilaria (MF) Status**					
			Positive (%)	Negative (%)	COR [95% CI]	p-value	AOR [95% CI]	p-value
Gender	Male	447 (63.8)	157 (35.1)	290 (64.9)	1.607 [1.140-2.266]	0.007*	1.620 [1.144-2.295]	0.007*
	Female	254 (36.2)	64 (25.2)	190 (74.8)	1.000		1.000	
Age (years)	12-22	52 (7.4)	24 (46.2)	28 (53.8)	1.00		1.000	
	23-33	113 (16.1)	43 (38.1)	70 (61.9)	0.717 [0.369-1.393]	0.326	0.731 [0.372-1.434]	0.362
	34-44	220 (31.4)	72 (32.7)	148 (67.3)	0.568 [0.307-1.048]	0.070	0.615 [0.329-1.149]	0.127
	45-55	241 (34.4)	61 (25.3)	180 (74.7)	0.395 [0.213-0.733]	0.003*	0.446 [0.236-0.836]	0.012*
	≥56	75 (10.7)	21 (28.0)	54 (72.0)	0.454 [0.216-0.953]	0.037*	0.578 [0.266-1.258]	0.167
Years lived in endemic area	<20 yrs.	282 (40.2)	95 (43.7)	187 (66.3)	1.000		-	-
	≥20 yrs.	419 (59.8)	126 (30.1)	293 (69.9)	0.846 [0.613-1.170]	0.312	-	-

IVM intake (MDA)	Compliance	668 (95.3)	204 (30.5)	464 (69.5)	1.000		1.000	
	Non-Compliance	33 (4.7)	17 (51.5)	16 (48.5)	2.417 [1.197-4.878]	0.014*	2.938 [1.259-6.856]	0.013*
Number of rounds of IVM intake (MDA)	0	33 (4.7)	17 (51.5)	16 (48.5)	1.000		1.000	
	1-5	553 (78.9)	178 (32.2)	375 (67.8)	0.447 [0.221-0.905]	0.025*	1.523 [0.928-2.499]	0.096
	>5	115 (16.4)	26 (22.6)	89 (77.4)	0.275 [0.122-0.618]	0.002*	-	-

***, Statistically significant p-values (p < 0.05); COR, Crude Odds Ratio; AOR, Adjusted Odds Ratio; CI, Confidence interval**

Leading reasons for non-adherence bordered on fear of adverse events and the misconception that the drug is meant for sick people. Others expressed reasons due to pregnancies, being absent during MDAs, refusal to take the drugs, and not being in good health [Fig. 3].

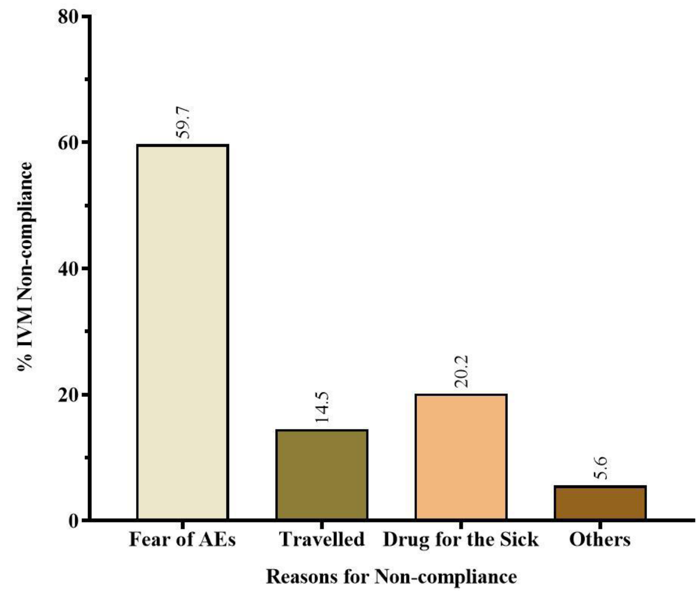

Fig. 5: Reasons for non-compliance with ivermectin MDA

Bivariate modelling analyses for Onchocerciasis infection in Sefwi Akontombra district

Binary logistic regression analyses (modelling) were done for gender, age, years lived in endemic area, IVM/MDA intake (compliance) and number of rounds of IVM intake to determine the variables fit to be included in the multivariate model, which independently predicts the chances of an individual being infected with *Onchocerca volvulus*. From the bivariate model, all variables included showed statistically significant associations (p<0.05) with *Onchocerca* nodules [Table V]. Except for years lived in endemic area (p=0.312), all other variables in the bivariate modelling were also significantly associated with onchocerciasis MF infection (p<0.05) [Table VI].

Multivariate modelling analyses of independent predictors of onchocerciasis infection in the Sefwi Akontombra district

Variables that were significantly associated with *Onchocerca* nodules and MF infection in the bivariate analysis were entered into the multivariate model to determine factors that exclusively and independently predicted the odds of an individual developing onchocerciasis infection. From the model, gender, age and IVM intake (MDA) stood out as independent predictors for the infection with the latter being significantly predictive of only MF detection (p=0.013). A male individual was twice more likely to develop *Onchocerca* nodules as compared to a female [AOR=2.388, CI=1.967 – 2.898] and this was also the case for MF infection among participants [AOR=1.620, CI=1.144 – 2.295] [Tables V and VI]. Also, an adult in the 45 – 55-year age group had nearly four times increased odds of harbouring *Onchocerca* nodules compared to individuals in the 12 – 22-year age group [AOR=3.758, CI=2.583 – 5.467] but this was not the case for MF infection [AOR=0.446, CI=0.236 – 0.836] [Tables V and VI]. Regarding IVM/MDA intake, individuals who were non-compliant to MDA were almost three times more likely to develop onchocerciasis infection compared to those in the compliant group [AOR=2.938, CI=1.259 – 6.856] [Table VI].

DISCUSSION

Despite over 40 years of sustained mass drug administration (MDA) efforts, onchocerciasis remains endemic in certain districts of Ghana, with significant public health implications, particularly concerning ocular and dermatological complications (Biritwum *et al.*, 2021). This study provides a crucial assessment of the impact of ivermectin (IVM)-based MDA on onchocerciasis prevalence in Sefwi Akontombra, a district previously classified as mesoendemic. The findings contribute to evaluating the Ghana Onchocerciasis Control Programme's (GOCP) progress and inform targeted interventions in other endemic districts within the Western North Region. Historical data indicate a decline in onchocerciasis prevalence following the introduction of MDA. In 2008, the Western Region recorded nodule and microfilaria (MF) prevalence rates of 2.89% and 3.57%, respectively (Biritwum *et al.*, 2021). Our findings, however, show that 35.4% of participants presented with *Onchocerca* nodules, with 31.5% of these nodule positives testing MF-positive.

Nonetheless, the persistence of high MF and nodule prevalence despite decades of MDA suggests ongoing transmission challenges. One possible factor is the one-year MDA disruption due to COVID-19, as observed in other vector-borne disease control programs (Hamley *et al.*, 2021). However, existing studies suggest that missing one or two rounds of MDA does not result in an immediate surge in infection rates (Arndts *et al.*, 2014), raising questions about other factors driving transmission. Additionally, our study restricted skin snipping to participants with palpable nodules, potentially underestimating true MF prevalence, as individuals without nodules can still harbour skin microfilariae (Remme *et al.*, 1986; Debrah *et al.*, 2006; Osei-Atweneboana *et al.*, 2007; WHO, 2016). The absence of Ov-16 ELISA or skin snip PCR testing, both of which offer higher diagnostic sensitivity than microscopy (WHO, 2016), is another limitation. Nonetheless, the large sample size aligns with WHO guidelines for MDA cessation and elimination verification, ensuring statistical robustness in our prevalence estimates (WHO, 2016). Our study found a significant association between gender and onchocerciasis burden, with men twice as likely as women to develop subcutaneous nodules and MF positivity. This disparity aligns with occupational exposure patterns, as men primarily engage in farming activities near the Tano River, a known breeding site for Simulium vectors. The higher exposure to infective blackfly bites among male farmers contrasts with women, who are predominantly engaged in trade and domestic work (Ghana Statistical Service, 2014). Moreover, differences in clothing, outdoor activity duration, and behavioural factors have been reported to influence blackfly biting rates across various cultural settings (Filipe *et al.*, 2005). However, some studies have found the reverse trend, where onchocerciasis prevalence was higher in females (Anosike *et al.*, 2001; Opara *et al.*, 2008). Such inconsistencies warrant further research into gender-based exposure variations and potential immunological differences influencing susceptibility. Onchocerciasis prevalence in Ghana has significantly declined, from 69.13% in 1975 to 0.72% in 2015, with a corresponding reduction in the community microfilarial load (CMFL) from 14.48 MF/ss to 0.07 MF/ss (Biritwum *et al.*, 2021). However, our study recorded a mean CMFL of 0.25 MF/ss in Sefwi Akontombra, which, while below the 5.0 MF/ss public health concern threshold (Onchocerciasis Control Programme in West Africa, 2002), remains higher than Ghana's 2015 national average of 0.07 MF/ss. The highest CMFL (0.77 MF/ss) was recorded in Adawu, a commercial hub that receives frequent migrants and traders from surrounding communities. This mobility could contribute to sustained transmission cycles. Given the nearly three decades of continuous MDA, the persistence of relatively high MF loads suggests that other factors, such as treatment fatigue, sub-optimal IVM response, or re-invasion from untreated areas, may be influencing transmission. Among the 1980 study participants, 6.3% had never taken IVM, a significantly lower non-compliance rate than 35.4% reported in Nigeria (Akafyi *et al.*, 2021). This lower rate suggests a higher awareness and acceptance of MDA programs in Ghana. Importantly, MDA compliance was significantly associated with lower MF positivity, with non-compliant individuals nearly three times more likely to be infected. This underscores the critical role of high MDA coverage in interrupting transmission cycles. However, fear of adverse effects (59.7%) and the misconception that IVM is meant only for the sick (20.2%) emerged as key barriers to compliance, mirroring findings from Cameroon and other endemic regions (Senyonjo *et al.*, 2016). While community MDA registers indicate high coverage (~85%), self-reported compliance in our study was 93.7%, surpassing Ghana's 2016 national MDA coverage of 83.8% (Biritwum *et al.*, 2021)a combination of approaches including vector control, mobile community ivermectin treatment, and community-directed treatment with ivermectin (CDTI. However, high coverage does not necessarily equate to high compliance, as individuals may collect but not ingest the medication (Babu and Babu, 2014; Dicko *et al.*, 2020). Our study did not assess actual IVM ingestion rates, a critical metric that future compliance studies should explore to ensure the effectiveness of MDA campaigns. IVM, though effective as a microfilaricide, has limited macrofilaricidal effects (Hoerauf, 2008). Consequently, some individuals exhibit sub-optimal responses, leading to persistent microfilaridermia despite repeated treatment (Awadzi *et al.*, 2004a, 2004b; Osei-Atweneboana *et al.*, 2011). This necessitates the integration of macrofilaricidal therapies to accelerate onchocerciasis elimination. Doxycycline has demonstrated promise as a macrofilaricide, targeting Wolbachia endosymbionts essential for *O. volvulus* survival (Hoerauf, 2008). However, its prolonged administration (4-6 weeks), contraindications in children <8 years, and logistical challenges hinder large-scale deployment (Hoerauf, 2008; Holmes and Charles, 2009). In response, our study enrolled MF-positive individuals into a clinical trial evaluating anti-Wolbachia drugs, funded by the European and Developing Countries Clinical Trials Partnership (EDCTP 2). If successful, these drugs could provide a shorter, more effective treatment regimen, significantly reducing transmission rates. Future efforts should prioritise alternative treatment regimens that can enhance the macrofilaricidal effect of IVM, ultimately fast-tracking onchocerciasis elimination. Among participants with dermal onchocerciasis, acute papular onchodermatitis (41.2%) was the most common clinical symptom, followed by sowda and atrophic skin (29.4% each). Similar findings have been reported in other Ghanaian studies (Otabil *et al.*, 2019). The pathophysiology of onchodermatitis is linked to intense immune responses against migrating MF, which trigger pruritus, inflammation, and subsequent skin atrophy (Sufi *et al.*, 2015; Noormahomed *et al.*, 2016; Okulicz *et al.*, 2018). All participants with clinical symptoms were MF-positive, reinforcing the strong association between microfilaridermia and dermal manifestations. Age was significantly associated with onchocerciasis risk, but trends varied for MF vs. nodule prevalence. The 45-55-year group had four times higher odds of developing nodules compared to the 12-22-year group, reflecting cumulative parasite exposure over time. However, MF prevalence was highest in the 12-22-year group, contradicting studies that found higher MF rates in older populations (Kifle *et al.*, 2019; Gebrezgabiher *et al.*, 2020).This may be due to behavioural factors, as older individuals are more aware of transmission risks and practice protective measures, while younger individuals may have higher exposure due to outdoor activities.

Limitations and strengths of the study

The study used purposive selection and convenience sampling, which may not be fully representative of the district's population. Also, only nodule-positive individuals underwent skin snipping, potentially underestimating true microfilarial prevalence. Self-reported treatment history was cross-verified with community health records, but recall errors may still affect accuracy. Visual impairment due to onchocerciasis was not evaluated, which could provide additional insights into disease burden. Notwithstanding, our study has several strengths. The study examined 1,980 participants across 25 communities, providing a robust dataset that enhances statistical reliability and representativeness. Also, the study combined clinical examination (nodule detection) and parasitological assessment (microfilariae detection) to enhance diagnostic accuracy. Furthermore, the findings build upon decades of MDA implementation, offering valuable insights into the long-term impact of ivermectin treatment on onchocerciasis transmission. Again, the study provides strong statistical evidence on how gender, age, and non-compliance influence persistent onchocerciasis transmission, guiding targeted interventions. In addition, our study is the first comprehensive assessment of onchocerciasis prevalence and transmission dynamics in the Western North Region after decades of MDA. Lastly, the results emphasise the need for alternative treatment approaches (e.g., anti-Wolbachia therapy) and enhanced community engagement, which can inform national and regional onchocerciasis control programs.

CONCLUSION

While mass drug administration (MDA) has significantly reduced the burden of onchocerciasis in the Sefwi Akontombra district, persistent microfilarial loads and localised transmission hotspots highlight the urgent need for enhanced intervention strategies. Moving forward, the following actionable recommendations should be prioritised:

1.**Strengthening MDA Compliance and Community Engagement** – Intensify community sensitisation efforts to address misconceptions and fear of adverse effects, ensuring higher ivermectin uptake, especially among non-compliant individuals and transient populations.

2.**Integrating Alternative Treatment Strategies** – Implement anti-Wolbachia therapies alongside ivermectin to enhance macrofilaricidal effects and accelerate the elimination timeline.

3.**Enhancing Surveillance and Diagnostic Approaches** – Expand diagnostic capacity by incorporating Ov-16 ELISA and PCR-based techniques to improve sensitivity in detecting residual transmission.

4.**Targeting High-Risk Groups** – Develop specialised intervention strategies focusing on occupationally exposed populations, such as farmers and fishermen, who are at greater risk due to proximity to blackfly breeding sites.

5.**Strengthening Cross-Border Collaboration** – Partner with neighbouring districts and regions to coordinate elimination strategies, mitigating reinfection risks from untreated areas.

By implementing these targeted approaches, Ghana can move closer to achieving the WHO's 2030 onchocerciasis elimination goals, ensuring lasting public health gains for affected communities.

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Declaration of conflict of interest

The authors declare that they have no competing interests.

REFERENCES

Adu Mensah, D., Debrah, L.B., Gyamfi, P.A., Rahamani, A.A., Opoku, V.S., Boateng, J., Obeng, P., Osei-Mensah, J., Kroidl, I., Klarmann-Schulz, U. and others (2022) 'Occurrence of Lymphatic Filariasis infection after 15 years of mass drug administration in two hotspot districts in the Upper East Region of Ghana', PLoS Neglected Tropical Diseases, 16(8), p. e0010129. Available at: https://doi.org/10.1371/journal.pntd.0010129

Akafyi, D.E., Ndams, I.S., Nock, H.I., Chechet, G. and Elkanah, S.O. (2021) 'Ivermectin Non-Compliance In Some Onchocerciasis Endemic Areas In Northern Nigeria ', International Journal of Science for Global Sustainability, 7(1 SE-Articles), p. 8. Available at: https://fugus-ijsgs.com.ng/index.php/ijsgs/article/view/53.

Anosike, J.C., Onwuliri, O.E., Onwuliri, V.A. and others (2001) 'The prevalence, intensity and clinical manifestations of Onchocerca volvulus infection in Toro local government area of Bauchi State, Nigeria', International journal of hygiene and environmental health, 203(5–6), pp. 459–464. Available at: https://doi.org/10.1078/1438-4639-00052

Arndts, K., Specht, S., Debrah, A.Y., Tamarozzi, F., Klarmann Schulz, U., Mand, S., Batsa, L., Kwarteng, A., Taylor, M., Adjei, O. and others (2014) 'Immunoepidemiological profiling of onchocerciasis patients reveals associations with microfilaria loads and ivermectin intake on both individual and community levels', PLoS neglected tropical diseases, 8(2), p. e2679. Available at: https://doi.org/10.1371/journal.pntd.0002679

Awadzi, K., Attah, S.K., Addy, E.T., Opoku, N.O., Quartey, B.T., Lazdins-Helds, J.K., Ahmed, K., Boatin, B.A., Boakye, D.A. and Edwards, G. (2004) 'Thirty-month follow-up of sub-optimal responders to multiple treatments with ivermectin, in two onchocerciasis-endemic foci in Ghana', Annals of Tropical Medicine \& Parasitology, 98(4), pp. 359–370. Available at: https://doi.org/10.1179/000349804225003442

Awadzi, K., Boakye, D.A., Edwards, G., Opoku, N.O., Attah, S.K., Osei-Atweneboana, M.Y., Lazdins-Helds, J.K., Ardrey, A.E., Addy, E.T., Quartey, B.T. and others (2004) 'An investigation of persistent microfilaridermias despite multiple treatments with ivermectin, in two onchocerciasis-endemic foci in Ghana', Annals of Tropical Medicine \& Parasitology, 98(3), pp. 231–249. Available at: https://doi.org/10.1179/000349804225003253

Babu, B. V and Babu, G.R. (2014) 'Coverage of, and compliance with, mass drug administration under the programme to eliminate lymphatic filariasis in India: a systematic review', Transactions of the Royal Society of Tropical Medicine and Hygiene, 108(9), pp. 538–549. Available at: https://doi.org/10.1093/trstmh/tru057

Batsa Debrah, L., Klarmann-Schulz, U., Osei-Mensah, J., Dubben, B., Fischer, K., Mubarik, Y., Ayisi-Boateng, N.K., Ricchiuto, A., Fimmers, R., Konadu, P. and others (2020) 'Comparison of repeated doses of ivermectin versus ivermectin plus albendazole for the treatment of onchocerciasis: a randomized, open-label, clinical trial', Clinical Infectious Diseases, 71(4), pp. 933–943. Available at: https://doi.org/10.1093/cid/ciz889

Biritwum, N.-K., de Souza, D.K., Asiedu, O., Marfo, B., Amazigo, U.V. and Gyapong, J.O. (2021) 'Onchocerciasis control in Ghana (1974–2016)', Parasites & Vectors, 14(1), p. 3. Available at: https://doi.org/10.1186/s13071-020-04507-2.

Debrah, A.Y., Mand, S., Marfo-Debrekyei, Y., Larbi, J., Adjei, O. and Hoerauf, A. (2006) 'Assessment of microfilarial loads in the skin of onchocerciasis patients after treatment with different regimens of doxycycline plus ivermectin', Filaria Journal, 5(1), pp. 1–10. Available at: https://doi.org/10.1186/1475-2883-5-1.

Dicko, I., Coulibaly, Y.I., Sangaré, M., Sarfo, B. and Nortey, P.A. (2020) 'Non-compliance to mass drug administration associated with the low perception of the community members about their susceptibility to lymphatic filariasis in Ankobra, Ghana', Infectious Disorders-Drug TargetsDisorders), 20(2), pp. 167–174. Available at: https://doi.org/10.2174/1871526519666190206210808

Filipe, J.A.N., Boussinesq, M., Renz, A., Collins, R.C., Vivas-Martinez, S., Grillet, M.-E., Little, M.P. and Basáñez, M.-G. (2005) 'Human infection patterns and heterogeneous exposure in river blindness', Proceedings of the Natio nal Academy of Sciences, 102(42), pp. 15265–15270. Available at: https://doi.org/10.1073/pnas.0502659102

Gebrezgabiher, G., Mekonnen, Z., Yewhalaw, D. and Hailu, A. (2020) 'Status of parasitological indicators and morbidity burden of onchocerciasis after years of successive implementation of mass distribution of ivermectin in selected communities of Yeki and Asosa districts, Ethiopia', BMC Public Health, 20, pp. 1–15. Available at: https://doi.org/10.1186/s12889-020-09344-7

Ghana Statistical Service. (2021). Ghana 2021 Population and Housing Census General Report Volume 3A Population of Regions and Districts. https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021 PHC General Report Vol 3A_Population of Regions and Districts_181121.pdf

Hamley, J.I.D., Blok, D.J., Walker, M., Milton, P., Hopkins, A.D., Hamill, L.C., Downs, P., De Vlas, S.J., Stolk, W.A. and Basáñez, M.-G. (2021) 'What does the COVID-19 pandemic mean for the next decade of onchocerciasis control and elimination?', Transactions of The Royal Society of Tropical Medicine and Hygiene, 115(3), pp. 269–280. Available at: https://doi.org/10.1093/trstmh/traa193

Hoerauf, A. (2008) 'Filariasis: new drugs and new opportunities for lymphatic filariasis and onchocerciasis', Current opinion in infectious diseases, 21(6), pp. 673–681. Available at: https://doi.org/10.1097/qco.0b013e328315cde7

Hofman, P. (2016) 'Infectious Disease and Parasites', Feline Practice. Edited by P. Hofman. Cham: Springer International Publishing (Encyclopedia of Pathology). Available at: https://doi.org/10.1007/978-3-319-30009-2.

Holmes, N.E. and Charles, P.G.P. (2009) 'Safety and efficacy review of doxycycline', Clinical Medicine. Therapeutics, 1, p. CMT--S2035. Available at: https://doi.org/10.4137/CMT.S2035

Katabarwa, M.N., Eyamba, A., Nwane, P., Enyong, P., Kamgno, J., Kueté, T., Yaya, S., Aboutou, R., Mukenge, L., Kafando, C. and others (2013) 'Fifteen years of annual mass treatment of onchocerciasis with ivermectin have not interrupted transmission in the west region of Cameroon', Journal of parasitology research, 2013(1), p. 420928. Available at: https://doi.org/10.1155/2013/420928

Kifle, B., Woldemichael, K. and Nigatu, M. (2019) 'Prevalence of Onchocerciasis and Associated Factors among Adults Aged [greater than or equal to] 15 Years in Semen Bench District, Bench Maji Zone, Southwest Ethiopia: Community Based Cross-Sectional Study', Advances in Public Health [Preprint]. Available at: https://doi.org/10.1155/2019/7276230

Ministry of Finance. (2023). Composite Budget for 2023-2026 Programme Based Budget Estimates for 2023—Sefwi Akontombra District Assembly. https://www.mofep.gov.gh/sites/default/files/composite-budget/2023/WN/Akontombra.pdf

Ministry of Finance. (2025). Composite Budget for 2025-2028 Programme Based Budget Estimates for 2025—Sefwi Akontombra District Assembly. https://doi.org/10.1017/cbo9781316151938.089

Nartey, E. T., Asare, R. A., Aforleho, P., Nseibi, I., Ampofo, A., and Sosu, M. (2023). Factors Influencing Family Planning Uptake Among Women of Reproductive Age in the Sefwi Akontombra District of Western North Region, Ghana. International Journal of Innovative Science and Research Technology, 8(6), 1413–1437.

Noormahomed, E. V, Akrami, K. and Mascaró-Lazcano, C. (2016) 'Onchocerciasis, an undiagnosed disease in Mozambique: identifying research opportunities', Parasites & Vectors, 9(1), p. 180. Available at: https://doi.org/10.1186/s13071-016-1468-7.

Okulicz, J.F., Elston, D.M. and Schwartz, R.A. (2018) 'Dermatologic manifestations of onchocerciasis (river blindness): background, pathophysiology, etiology'. Available at: https://emedicine.medscape.com/article/1109409-overview

Onchocerciasis Control Programme in West Africa (2002) 'Summary Report of the OCP / TDR meeting on the impact of ivermectin on onchocerciasis transmission Summary Report of the OCP / TDR meeting on the impact of ivermectin on onchocerciasis transmission', (October 2001). Available at: https://iris.who.int/bitstream/handle/10665/311607/EAC-AD.2-eng.pdf?sequence=2&isAllowed=y

Opara, K.N., Usip, L.P., Akpabio, E.E. and others (2008) 'Transmission dynamics of Simulium damnosum in rural communities of Akwa Ibom State, Nigeria', J Vector Borne Dis, 45, pp. 225–230. Available at: https://pubmed.ncbi.nlm.nih.gov/18807379/

Osei-Atweneboana, M.Y., Awadzi, K., Attah, S.K., Boakye, D.A., Gyapong, J.O. and Prichard, R.K. (2011) 'Phenotypic evidence of emerging ivermectin resistance in Onchocerca volvulus', PLoS neglected tropical diseases, 5(3), p. e998. Available at: https://doi.org/10.1371/journal.pntd.0000998

Osei-Atweneboana, M.Y., Eng, J.K., Boakye, D.A., Gyapong, J.O. and Prichard, R.K. (2007) 'Prevalence and intensity of Onchocerca volvulus infection and efficacy of ivermectin in endemic communities in Ghana: a two-phase epidemiological study', The Lancet, 369(9578), pp. 2021–2029. Available at: https://doi.org/10.1016/S0140-6736(07)60942-8.

Otabil, K.B., Gyasi, S.F., Awuah, E., Obeng-Ofori, D., Atta-Nyarko, R.J., Andoh, D., Conduah, B., Agbenyikey, L., Aseidu, P., Ankrah, C.B. and others (2019) 'Prevalence of onchocerciasis and associated clinical manifestations in selected hypoendemic communities in Ghana following long-term administration of ivermectin', BMC Infectious Diseases, 19, pp. 1–7. Available at: https://doi.org/10.1186/s12879-019-4076-2

Remme, J., Ba, O., Dadzie, K.Y. and Karam, M. (1986) 'A force-of-infection model for onchocerciasis and its applications in the epidemiological evaluation of the Onchocerciasis Control Programme in the Volta River basin area.', Bulletin of the World Health Organization, 64(5), pp. 667–81. Available at: https://pubmed.ncbi.nlm.nih.gov/3492300/

Senyonjo, L., Oye, J., Bakajika, D., Biholong, B., Tekle, A., Boakye, D., Schmidt, E. and Elhassan, E. (2016) 'Factors associated with ivermectin non-compliance and its potential role in sustaining Onchocerca volvulus transmission in the west region of Cameroon', PLoS neglected tropical diseases, 10(8), p. e0004905. Available at: https://doi.org/10.1371/journal.pntd.0004905

Shintouo, C.M., Nguve, J.E., Asa, F.B., Shey, R.A., Kamga, J., Souopgui, J., Ghogomu, S.M. and Njemini, R. (2020) 'Entomological assessment of onchocerca species transmission by black flies in selected communities in the west region of Cameroon', Pathogens, 9(9), p. 722. Available at: https://doi.org/10.3390/pathogens9090722

Sufi, D.A., Zainab, T. and others (2015) 'Evaluation of Onchocerciasis: A decade of post treatment with ivermectin in Zainabi and Ririwai Doguwa local government area of Kano State', Advances in Entomology, 3(01), p. 1. Available at: http://dx.doi.org/10.4236/ae.2015.31001

The Permanent Mission of Ghana to the United Nations (2021) Map & Regions in Ghana. Available at: https://www.ghanamissionun.org/map-regions-in-ghana/

Tsapi, E.M., Todjom, F.G., Gamago, G.-A., Pone, J.W. and Teukeng, F.F.D. (2020) 'Prevalence of onchocerciasis after seven years of continuous community-directed treatment with ivermectin in the Ntui health district, Centre region, Cameroon', Pan African Medical Journal, 36(1). Available at: https://doi.org/10.11604/pamj.2020.36.180.20765

WHO (2010) 'Conceptual and Operational Framework of Onchocerciasis Elimination with Ivermectin Treatment', World Health Organization, 6(Ii), pp. 1–22. Available at: https://iris.who.int/bitstream/handle/10665/27 5466/JAF16.6-II-eng.pdf

WHO (2016) 'Guidelines for stopping mass drug administration and verifying elimination of human onchocerciasis : criteria and procedures.', Who, p. 36. Available at: http://apps.who.int/iris/bitstream/10665/204180/1/9789241510011_eng.pdf?ua=1.

World Health Organization (2020) Ending the neglect to attain the sustainable development goals: a road map for neglected tropical diseases 2021–2030., Who. Available at: https://iris.who.int/bitstream/handle/10665/338565/9789240010352-eng.pdf?sequence=1

World Health Organization (2022) Onchocerciasis. Available at: https://www.who.int/news-room/fact-sheets/detail/onchocerciasis (Accessed: 26 February 2025)