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Health Inequities in Schistosomiasis Burden and Treatment Outcomes: A Comparative Study of Enrolled and Out-of-School Children in Riverine Kebbi State

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Abstract

Schistosomiasis remains endemic in Nigeria, disproportionately affecting out-of-school children (OOSC), who are largely excluded from mass drug administration (MDA) programs. To compare *Schistosoma* spp prevalence, morbidity, and treatment outcomes between enrolled school children (ESC) and OOSC in Kebbi State. A community-based cross-sectional study with longitudinal follow-up (Oct 2023–Feb 2024) was conducted in six riverine communities. Diagnoses included urine filtration, Kato-Katz, and POC-CCA for hybrids. Multivariable Poisson regression assessed determinants. Of 1155 children (aged 0–15 years), overall infection prevalence was 11.4% (n=132). OOSC exhibited significantly higher prevalence than ESC (31.4% vs 5.2%, p<0.001). Key risk factors included stream water use (PR 3.45; 95% CI, 2.5–4.8), open defecation (PR 2.19; 95% CI, 1.7–2.9), and inadequate hygiene practices. Only 3.8% of infected children received praziquantel; traditional and spiritual healing were predominant. Charts illustrate infection by education, water source, and hygiene practices. The exclusion of OOSC sustains reservoirs of transmission and undermines the WHO's 2030 elimination targets. Integrated interventions, including community-based MDA, WASH, and hygiene, are urgently needed.

INTRODUCTION

Schistosomiasis remains one of the most pervasive neglected tropical diseases, posing a significant public health burden worldwide. An estimated 200 million people are infected globally, with over 90% of those requiring preventive treatment residing in sub-Saharan Africa [1,2]. The disease contributes substantially to morbidity, mortality, and socioeconomic loss, causing more than 200,000 deaths annually in the region and accounting for millions of disability-adjusted life years (DALYs) [3]. Despite decades of control efforts, persistent transmission, reinfection, and limited access to water, sanitation, and health services continue to sustain high endemicity in many African countries [2,4]. The disease manifests through chronic, systemic inflammation that causes anaemia, growth retardation, and cognitive impairment in children [2]. At the same time, urogenital forms increase susceptibility to HIV and HPV infections and cause female genital schistosomiasis (FGS) in up to 56 million women [5]. Despite substantial progress, schistosomiasis remains highly endemic in West Africa. According to a recent trend analysis using GBD 2021 data, the age-standardised prevalence rate (ASPR) of schistosomiasis in Africa dropped from 18,495.51 per 100,000 in 1990 to 9,461.76 per 100,000 in 2021, a decline of ~49% in ASPR [6]. Transmission, however, remains intense in certain ecological zones, driven by unsuitable water, sanitation, and hygiene infrastructure (WASH), environmental factors conducive to snail hosts, and gaps in mass drug administration coverage [6].

In Nigeria, schistosomiasis remains highly endemic, especially in the Northwest geopolitical zone. For example, in Argungu, Kebbi State, a school-based study found *Schistosoma haematobium* prevalence of 32.1% among children aged 7–14 [7]. In Silame, Sokoto State, prevalence among primary school children was 21.3%, with a higher burden in boys and associated with sources of water contact [8]. In contrast, in Kano State, the overall prevalence of schistosomiasis was 17.8%, comprising 8.9% infected with *Schistosoma mansoni*, 8.3% with *Schistosoma haematobium*, and *0.5%* presenting co-infection with both species [9]. Another survey in Sokoto showed extraordinarily high urinary schistosomiasis rates of 60.8% in certain communities [10]. According to a 2023 national review, Nigeria's burden is estimated at some 20 million infected individuals, with the Northwest being the most severely affected among Nigeria's zones [11].

The World Health Organization's schistosomiasis control strategy, which centres on preventive chemotherapy through school-based mass drug administration (MDA) of praziquantel targeting school-aged children, is credited with reducing the prevalence of schistosomiasis by approximately 60% among school-aged children in sub-Saharan Africa over the past two decades [12,13]. However, critical inequities exist: approximately 18.3 million Nigerian children are out of school, largely due to insecurity, poverty, and inadequate educational infrastructure [14,15]. Kebbi State has been reported in media sources to have among the highest out-of-school rates (≈ 67.6%), though peer-reviewed confirmation of that exact percentage is limited. These out-of-school children are systematically excluded from school-based mass drug administration (MDA) programs, creating a reservoir for ongoing transmission and morbidity [16,17]. The 2021–2030 WHO Roadmap for Neglected Tropical Diseases explicitly identifies the need to extend preventive chemotherapy to all population groups in need and address persistent hotspots through micro-targeting [18]. Yet, OOSC remains a neglected demographic in surveillance and intervention design.

The paucity of comparative data on schistosomiasis burdens between ESC and OOSC impedes evidence-based programming. Current burden estimates rely heavily on school-based surveys, which underestimate community prevalence by excluding high-risk OOSC. Furthermore, hybrid strains of *S. haematobium* and *S. bovis* have been increasingly documented in West Africa. These introgressed parasites have the potential to complicate both diagnostics (due to altered genetic markers, egg morphology, and transmission dynamics) and control strategies [19,20]. Additionally, ecological factors such as seasonal flooding in the riverine Kebbi exacerbate transmission [7]. This study aims to: (1) quantify prevalence, infection intensity, and morbidity disparities between ESC and OOSC; (2) identify sociodemographic, WASH, and environmental determinants of inequities; and (3) evaluate treatment access gaps. Findings will inform equity-oriented interventions to accelerate elimination in Nigeria and comparable settings.

METHODS

Study Design and Setting

A community-based, cross-sectional study with a longitudinal component for treatment outcome assessment was meticulously conducted between October 2023 and February 2024 in Kebbi State, Nigeria. Kebbi State, situated within the expansive Niger River basin, is characterised by its unique ecological features, including pronounced seasonal flooding, extensive irrigation networks, and a high density of intermediate host snails, specifically *Bulinus* and *Biomphalaria* species. These environmental factors collectively contribute to a highly endemic setting for schistosomiasis. To ensure a representative sample of the affected population, six riverine communities were purposely selected across three local government areas (LGAs). These communities were defined as being located within 5 kilometres of permanent water bodies, thereby ensuring their direct exposure to potential transmission sites. The selection of LGAs and communities was performed using probability proportional to size (PPS) sampling, a robust method to account for variations in population density and ensure statistical representativeness.

Participant Recruitment and Sampling

A rigorous multi-stage cluster sampling design was employed to recruit study participants, focusing on children aged 0-15 years. This age group was specifically targeted due to their heightened vulnerability to schistosomiasis infection and their critical role in transmission dynamics. The sampling process unfolded as follows:

Three high-burden LGAs within Kebbi State were purposively selected based on epidemiological surveillance data from the Expanded Special Project for Elimination of Neglected Tropical Diseases (ESPEN). From each LGA, two riverine communities were chosen using probability proportional to size (PPS) sampling, ensuring representativeness while focusing on endemic riverine areas. Within the selected communities, households were enumerated and children aged 0–15 years were recruited through community outreach by local health workers and leaders, a strategy that was particularly important for engaging out-of-school children (OOSC) who are often missed by school-based interventions.

Sample Size Calculation

The sample size was meticulously calculated to ensure adequate statistical power for detecting significant differences between enrolled school children (ESC) and OOSC. Based on an assumed prevalence of schistosomiasis of 35% among OOSC in similar settings [21–23], a statistical power of 80%, a 5% alpha error, and a design effect of 2.0 (to account for the cluster sampling design), a minimum of 780 children were required. An additional 30% was added to account for potential non-response, bringing the total target sample size to approximately 1155 children. Enrolled school children (ESC) were sampled from schools within the selected communities using random classroom roster selection, ensuring an unbiased selection from the school population. Out-of-school children (OOSC) were identified and recruited through close collaboration with community health workers and through systematic household surveys, specifically targeting children not attending formal education.

Inclusion Criteria

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Participants were included if they met the following criteria: (1) resided in the selected community for a minimum of six months; (2) were aged between 0 to 15 years; and (3) provided written guardian consent and child assent. The process for obtaining informed consent from guardians and assent from children was conducted in local languages, ensuring full comprehension and voluntary participation.

Exclusion Criteria
Children were excluded from the study if they presented with severe illness at the time of recruitment (assessed by a qualified medical professional based on clinical signs and symptoms) or had received any anti-helminthic treatment within the preceding four weeks, to avoid confounding the treatment outcome assessment.

Diagnostic Procedures and Data Collection
Comprehensive diagnostic procedures and data collection methods were employed to accurately assess schistosomiasis infection, intensity, and associated risk factors.

Parasitological Diagnosis

Stool Samples
Fresh stool samples were collected from all participants. Each sample was processed using the Kato-Katz thick smear technique (duplicate slides per sample, using 41.7 mg templates) for the quantitative detection of *Schistosoma mansoni* eggs. Slides were examined within one hour of preparation to prevent over-clearing of eggs. Two independent, experienced microscopists examined each slide, and in cases of discrepancy, a third senior microscopist resolved the difference. Egg counts were recorded, and infection intensity was classified according to WHO guidelines [24]. Where feasible, two stool specimens collected on consecutive days were examined (two slides per specimen).

Urine Samples
Urine was collected between 10:00 and 14:00; ≥10 mL mid-stream; mixed before filtration. Each sample was processed using the urine filtration technique through 12 µm polycarbonate filters for the quantitative detection of *Schistosoma haematobium* eggs. Filters were examined under a microscope, and egg counts were recorded. Infection intensity was classified as light infection: 1–49 eggs per 10 mL; heavy infection: ≥50 eggs per 10 mL of urine. Urinalysis RDTs (Hemastix®) were also performed on urine samples to detect microhaematuria, a common indicator of *S. haematobium* infection. The Hemastix® test was used as a rapid screening tool in the field. Urine point-of-care circulating cathodic antigen (POC-CCA) cassette tests were performed. This non-invasive urine-based test is widely used in field surveys because it is simple, rapid, and sensitive for *S. mansoni* diagnosis [24].

Infection Intensity
Infection intensity for both *S. mansoni* and *S. haematobium* was classified according to the World Health Organisation (WHO) guidelines [24]:

Light infection
1-99 eggs per gram of stool (EPG) for *S. mansoni* or 1-99 eggs per 10ml of urine for *S. haematobium*.
Moderate infection
100-399 EPG for *S. mansoni* or 100-399 eggs per 10ml of urine for *S. haematobium*.
Heavy infection
≥400 EPG for *S. mansoni* or ≥400 eggs per 10ml of urine for *S. haematobium*.

Surveys
Structured questionnaires were administered to caregivers or guardians via face-to-face interviews conducted by trained data collectors. Data was collected using Open Data Kit (ODK) software on digital tablets to ensure efficient and accurate data capture. The questionnaires gathered comprehensive information on socioeconomic status, demographics, water, sanitation, and hygiene (WASH) practices, and treatment access. All questionnaires were pre-tested in a pilot study in a non-study community to ensure clarity, cultural appropriateness, and validity.

Socioeconomic and Demographic Questionnaire
This survey captured data on age, gender, parental education level (categorised as no formal education, primary, secondary, tertiary), and household assets (e.g., radio, television, bicycle, motorcycle, livestock), which were used to construct a wealth index.

WASH Survey
Detailed information was collected on household water sources (e.g., pipe-borne, borehole, open well, stream/river), sanitation facility type (e.g., flush toilet, pit latrine, open defecation), and handwashing practices (e.g., frequency, use of soap). Specific questions also quantified river contact frequency and duration (e.g., daily, weekly, occasional; hours per day/week) for activities such as bathing, swimming, fishing, and farming.

Treatment Access Survey
This component assessed participants' history of participation in mass drug administration (MDA) programs and identified barriers to praziquantel coverage. Questions explored reasons for non-participation, perceived drug shortages, accessibility of health personnel, and the influence of insecurity on access to treatment. Information on reliance on traditional and spiritual healing practices was also gathered.

Data Analysis
Descriptive statistics were used to summarise the demographic, socioeconomic, and infection characteristics of the study population. Categorical variables were presented as frequencies and percentages, while continuous variables were summarised as means and standard deviations or medians and interquartile ranges, as appropriate. Prevalence ratios (PRs) were estimated using modified Poisson regression with robust standard errors clustered at the community level. Prevalence differences (PDs) were estimated using binomial regression models with an identity link function and robust standard errors. Models incorporated sampling weights to reflect probability proportional to size (PPS) sampling where applicable. All statistical analyses were conducted using SPSS Statistics version 27 (IBM Corp., Armonk, NY, USA). Two-sided p-values <0.05 were considered statistically significant.

Ethical Considerations
Ethical approval for the study was obtained from the Kebbi State Health Research Ethics Committee (KSHREC: 107:026/2023). Before data collection, community consent was secured through formal meetings with village heads and community leaders, ensuring their understanding and support for the study. Individual written informed consent was obtained from the parents or legal guardians of all participating children, and verbal assent was obtained from the children themselves, in a child-friendly manner. All data collected was anonymised to protect participant privacy and confidentiality. In line with ethical best practices and

data sharing policies, anonymised study data will be made publicly available via the WHO ESPEN portal upon publication, contributing to global health data repositories and facilitating further research.

RESULTS

Prevalence and Distribution

Of the 1,155 children aged 5-14 years who participated in the study, the overall prevalence of Schistosoma infection was found to be 11.4% (n = 132). A striking disparity in infection prevalence was observed between out-of-school children (OOSC) and enrolled school children (ESC). OOSC exhibited a significantly higher prevalence of infection at 31.4%, compared to ESC, which had a prevalence of only 5.2% (p<0.001) (**Fig. 1**).

As detailed in **Table 1**, the prevalence of schistosomiasis varied across the different LGAs and communities. The Gotomo community in Argungu LGA recorded the highest prevalence at 30.7%, highlighting localised hotspots of intense transmission. Conversely, the Bandam community in Suru LGA showed the lowest prevalence at 3.1%.

Table 1. Schistosomiasis prevalence by lga and community.

LGA	Community	*n*	Infected, n (%)
Argungu	Dangoje	193	15 (7.8)
	Gotomo	192	59 (30.7)
Bunza	Maidahini	193	20 (10.4)
	Raha	192	16 (8.3)
Suru	Aljannare	193	16 (8.3)
	Bandam	192	6 (3.1)
Total	-	1155	132 (11.4)

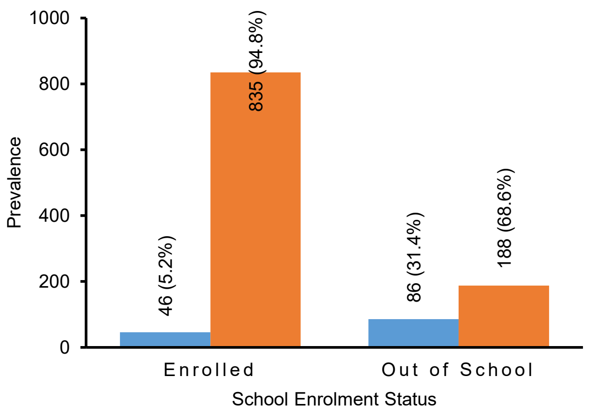

Fig. 1. Prevalence of schistosomiasis infection by school enrolment status.

Analysis by gender revealed that females had a higher prevalence of infection (19.7%) compared to males (8.9%), a finding that warrants further investigation into gender-specific water contact patterns and domestic roles. In terms of age distribution, children aged 0-5 years showed a higher prevalence of (14.0%) than those aged 6-10 (10.8%), and 11-15 years (9.3%) (**Table 2**).

Table 2. Schistosomiasis prevalence by gender and age group.

Category	Subgroup	Infected/Total (%)
Gender	Male	78/881 (8.9%)
	Female	54/274 (19.7%)
Age	0 -5 years	54/385 (14.0)
	6-10 years	46/424 (10.8%)
	11-15 years	32/346 (9.3%)

WASH and Behavioural Correlates

The study identified significant associations between schistosomiasis infection and various water, sanitation, and hygiene (WASH) practices, highlighting the critical role of environmental factors and human behaviour in disease transmission. Children relying on unsafe water sources and engaging in poor sanitation practices demonstrated markedly higher infection rates.

As shown in **Table 3**, access to improved water sources was inversely associated with schistosomiasis prevalence. Children who primarily used pipe-borne water had the lowest infection rate (6.4%), followed by those using boreholes (8.0%) and open wells (9.7%). In stark contrast, children who frequently used stream or river water for daily activities exhibited a significantly higher prevalence of 22.1%.

Table 3. Schistosomiasis infection prevalence by water source.

Water Source	Children (n)	Infected, n (%)
Pipe-borne	141	9 (6.4)
Borehole	188	15 (8.0)
Open well	268	26 (9.7)
Stream River	339	75 (22.1)

Table 4 illustrates the profound impact of sanitation practices on schistosomiasis prevalence. Children from households practising open defecation had an infection rate of 15.2%, more than double the rate observed among those using latrines (7.4%). This highlights the critical role of proper human waste disposal in preventing the contamination of water sources with *Schistosoma* eggs, thereby interrupting the parasite's life cycle and reducing transmission within the community.

Table 4. Schistosomiasis infection prevalence by defecation practices.

Sanitation Access	Children (n)	Infected, n (%)
Latrine use	526	39 (7.4)
Open defecation	512	78 (15.2)

Personal hygiene practices also played a significant role in infection risk, as presented in **Table 5**. Children who reported washing their hands with water and soap had a substantially lower prevalence of 6.0%. Conversely, those who used only water for hygiene purposes showed a much higher infection rate of 15.3%. A graphical summary for the outcome of schistosomiasis and water source, sanitation, and hygiene practices is shown in **Fig. 2**.

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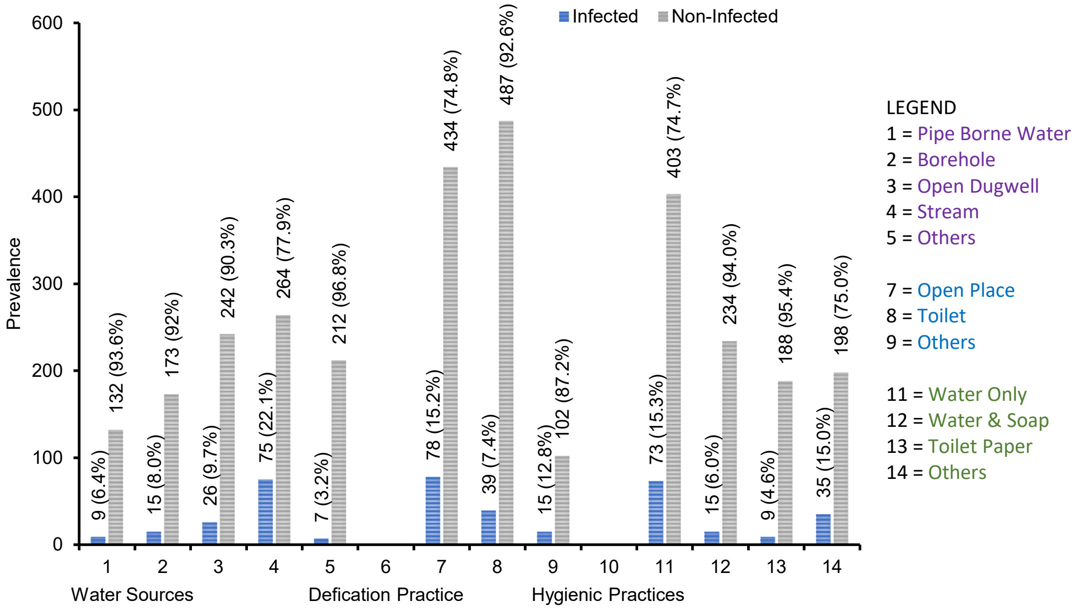

Fig. 2. Schistosomiasis prevalence by water source, sanitation, and hygiene practices.

Table 5. Schistosomiasis infection prevalence by hygiene practice.

Hygiene	Children (n)	Infected, n (%)
Water & soap	249	15 (6.0)
Water only	476	73 (15.3)

Treatment Access

Despite the observed high prevalence of schistosomiasis, particularly among OOSC, access to conventional praziquantel treatment was alarmingly low. Only 5 out of 132 (3.8%) infected children reported having received praziquantel historically. In the absence of formal medical intervention, the majority of infected children relied on alternative healing modalities: 38.6% sought treatment from traditional medicine practitioners, while a substantial 57.6% resorted to spiritual practices. Major barriers to praziquantel access reported by the community included a pervasive lack of health personnel, frequent drug shortages at local health facilities, and the pervasive issue of insecurity in certain areas, which hindered both drug distribution and community access to health services.

Multivariable Analysis

Following multivariable Poisson regression analysis, adjusting for potential confounding factors and clustering effects, several determinants were significantly associated with *Schistosoma* infection. Out-of-school children (OOSC) were 3.8 times more likely to be infected compared to enrolled school children (PR 3.8; 95% CI, 2.9–5.1; $p<0.001$). Children who reported using stream water as their primary source were 3.5 times more likely to be infected than those using improved water sources (PR 3.5; 95% CI, 2.5–4.8). The practice of open defecation was associated with a 2.2-fold increased likelihood of infection (PR 2.2; 95% CI, 1.7–2.9). Similarly, children practising water-only hygiene were 1.9 times more likely to be infected compared to those using water and soap (PR 1.9; 95% CI, 1.4–2.6).

DISCUSSION

Our study provides compelling evidence of marked health inequities in schistosomiasis burden, with out-of-school children (OOSC) in riverine Kebbi State demonstrating a five-fold higher likelihood of infection compared to their enrolled school counterparts. This finding confirms a substantial burden of schistosomiasis within riverine Kebbi communities and highlights a clear inequity faced by children outside the formal education system, who are excluded from school-based mass drug administration (MDA) programs. This disparity, confirmed through multivariable analysis (PR 3.8; 95% CI, 2.9–5.1), is consistent with patterns reported in other endemic settings, including Nigeria and Cameroon, where OOSC are increasingly recognised as reservoirs sustaining persistent transmission [12]. The systematic exclusion of OOSC from praziquantel delivery, despite their heightened exposure to infested water sources, creates a critical gap in current control strategies. This undermines the WHO's schistosomiasis elimination roadmap, which emphasises equitable access to preventive chemotherapy [18].

The observed associations between infection and water, sanitation, and hygiene (WASH) conditions further reinforce the vulnerability of affected communities. Children using unimproved water sources, especially streams and rivers, were 3.5 times more likely to be infected, mirroring global evidence that unsafe water access significantly increases schistosome risk [25]. This points to the central role of local environmental conditions, daily water contact behaviours, and inadequate WASH infrastructure in sustaining transmission [2]. Direct contact with infested natural water bodies remains a major route of infection in riverine communities, where such sources are widely relied upon for domestic, agricultural, and recreational purposes. This finding supports the urgent need for hygiene education and consistent handwashing practices to limit exposure to cercariae.

The role of sanitation and hygiene behaviours was equally significant. Open defecation doubled infection risk (PR 2.2), while children practising water-only handwashing were nearly twice as likely to be infected compared to those using water and soap. These results highlight that environmental contamination and poor hygiene practices are not peripheral concerns but fundamental drivers of schistosomiasis persistence [26]. This aligns with growing evidence that WASH interventions are not optional add-ons but critical elements for sustainable control and elimination [24]. The current WASH situation in Kebbi, where many boreholes are non-functional, illustrates the infrastructure challenges that amplify these risks and demonstrates the need for targeted investment in safe water provision [27].

Our findings also revealed notable gender differences, with females showing a higher prevalence of infection. This observation is in line with other studies from sub-Saharan Africa, where women and girls experience greater water contact due to household and domestic roles [28]. This gendered exposure suggests that control programs should explicitly consider the daily activities of girls and women in high-burden communities. Age-related differences were also observed: although not statistically significant, younger children (0–5 years) had slightly higher infection rates compared to older groups, possibly reflecting increased water play and less developed hygiene behaviours. This supports the inclusion of preschool-aged children in praziquantel distribution, a recommendation echoed by recent WHO guidelines [24]. These demographic patterns are important for designing interventions that prioritise the most vulnerable groups.

Treatment access remains alarmingly inadequate. Less than 4% of infected children reported ever receiving praziquantel, while most relied on traditional medicine (38.6%) or spiritual healing (57.6%). This strikingly low coverage demonstrates systemic barriers to treatment delivery in high-risk settings. Reported obstacles such as drug shortages, lack of health personnel, and insecurity echo findings from recent studies [29–31]. The widespread reliance on traditional and spiritual healers underscores the need for culturally sensitive, community-based approaches that build trust and promote uptake of praziquantel. Without addressing these barriers, current treatment gaps will continue to undermine elimination efforts.

Finally, the multivariable analysis reinforces that OOSC status, unsafe water use, open defecation, and limited hygiene are not isolated factors but interconnected determinants of schistosomiasis transmission. The strong and independent association between OOSC status and infection, even after adjusting for WASH variables, underlines their distinct vulnerability and confirms that excluding this group from school-based MDA perpetuates inequity. This situation reflects the broader economic and developmental costs of neglected tropical diseases, which disproportionately affect the poorest and most marginalised populations [9,25]. Addressing these inequities requires integrated strategies that combine community-based MDA, robust WASH interventions, and tailored health education to achieve sustainable progress toward elimination.

LIMITATIONS

While our study provides crucial insights, it is not without limitations. The cross-sectional design, while effective for assessing prevalence and associated factors at a single point in time, limits our ability to establish causality or track long-term treatment outcomes. Although we included a longitudinal component for treatment outcome assessment, the low praziquantel coverage limited the scope of this analysis. Furthermore, reliance on self-reported data for WASH practices and treatment history may be subject to recall bias. However, future longitudinal studies incorporating direct observation of WASH practices and more robust tracking of treatment uptake would provide a more comprehensive understanding of these dynamics.

CONCLUSION

The pronounced disparity in schistosomiasis infection among out-of-school children in Kebbi State underscores a critical public health challenge. Our findings highlight the urgent need to pivot from exclusively school-centric MDA strategies to more inclusive, community-based approaches that actively reach and treat OOSC. Reinforcing WASH infrastructure and promoting sustainable hygiene practices are equally vital to interrupt transmission cycles. Aligning with the WHO's 2021-2030 roadmap for neglected tropical diseases, Nigeria must expand praziquantel delivery beyond schools to encompass all at-risk population groups, including OOSC, to accelerate progress towards the 2030 elimination targets. Integrated interventions that combine preventive chemotherapy with improved WASH and targeted health education are essential for achieving health equity and sustainable control of schistosomiasis in Nigeria and comparable endemic settings.

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