Original Article

Environmental and Behavioural Factors Associated with Cryptosporidiosis among HIV/AIDS Patients in a Primary Health Centre in Northwestern Nigeria

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ABSTRACT
Cryptosporidium is one of the micro-organisms associated with diarrhoea in human immunodeficiency virus (HIV)/acquired immune deficiency syndrome (AIDS) patients. Diarrhoea remains one of the most important health problems globally and a leading cause of morbidity and mortality among immunocompromised individuals accounting for over 50 million deaths worldwide. This study was a cross-sectional study conducted in one of the primary healthcare centres in Northwestern part of Nigeria. Consented participants were administered a questionnaire to get information on their sociodemographic factors, risk factors, and behavioural practices. Stool samples were collected from HIV/AIDS positive patients and processed using formol formalin-ether concentration method. Smears were made from the sediment and stained using Modified Ziehl-Neelsen staining for the detection of oocysts of *Cryptosporidium.* The study recruited 185 HIV-positive patients with a 29.2% prevalence of *Cryptosporidium* infection, with higher rates among individuals aged 36–55 years. Females were slightly more affected than males. Environmental and behavioural factors played key roles, as infection was higher among those using tap water and pit latrines. Boiling water was found to be protective (p = 0.001), whereas contact with animals significantly increased infection risk (p = 0.025). The study showed a high *Cryptosporidium* infection rate (29.2%) among HIV/AIDS patients in Northwestern Nigeria, confirming it as a major opportunistic pathogen causing morbidity in immunocompromised individuals. Boiling water and environmental hygeine were identified as protective practices. The findings emphasize the need for improved hygiene, safe water practices, regular screening, and strengthened HIV management to reduce infection rates.
Keywords: Behavioural factor, Cryptosporidiosis, Diarrhoea, Environmental factors, HIV/AIDS

INTRODUCTION
Cryptosporidium species are protozoans belonging to Apicomplexa that infect man and other vertebrates.[1] Currently, more than 38 species of the parasite have been described worldwide, with *Cryptosporidium hominis* and *Cryptosporidium parvum* implicated in most human infections.[2,3] Intestinal parasites are endemic in many regions of the world where HIV/AIDS infection is also prevalent of which Sub-Saharan Africa being among such regions. In humans, the disease results in sickness and severe diarrhoea and can be life-threatening in young, elderly, or immunosuppressed individuals, particularly those with HIV infection.[4] *Cryptosporidium* infection in immunocompetent hosts usually presents with diarrhoea that is self-limiting but can be severe and prolonged in immunocompromised individuals, causing much more serious clinical signs, manifested as prolonged debilitating diarrhoea, weight loss, fever, and abdominal pain.[5] Therefore, cryptosporidiosis is a significant cause of chronic diarrhoea and death in HIV/AIDS patients.

Cryptosporidium has been reported in several studies among HIV-positive individuals around the world, with a prevalence ranging from 2.17% to 55% in China, Uganda, Kenya, Congo Democratic Republic, Ethiopia, and

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Nigeria.[6,7] In Nigeria, hospital-based studies among HIV-infected participants in Northern Nigerian regions have reported prevalences of 14% and 46%, respectively.[8] Methods available for the detection of *Cryptosporidium* infections in stool samples include conventional microscopy to identify oocysts on stained slides and immunological assays based on the detection of *Cryptosporidium* antigens by immunochromatography or enzyme-linked immunosorbent assay (ELISA). Currently, molecular methods such as real-time polymerase chain reaction (RT-PCR), polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP), and PCR sequencing protocols are used in the identification of genotypes/species of the parasite.[9] It must, however, be noted that most of the studies on *Cryptosporidium* in Nigeria utilized conventional microscopy. Although ELISA has proven in many cases to be more sensitive in the detection of *Cryptosporidium species* than microscopy, its use is however limited to a few studies in Nigeria.[10] Globally, HIV infections currently stand at about 39.4 million people, with adults (15 years and above) constituting 95% of the infected population. In developed countries with low rates of environmental contamination where potent ART is widely available, *cryptosporidiosis* occurs at an incidence of ≤ 1 per 100 persons among persons with AIDS.[11,12] In less developed countries like Nigeria, however, which has a high rate of uninhibited defecation, use of human faeces as manure, inadequate water supply, poor sanitary facilities and inadequate ART supplies, *Cryptosporidiosis* may be difficult to control.

MATERIALS AND METHODS

Study Area

Kaduna State is located in the northwestern part of Nigeria. It shares borders with seven states: Kano and Katsina to the north, Plateau and Nasarawa to the south, Zamfara to the west, and Bauchi and the Federal Capital Territory (Abuja) to the east. The state lies roughly between latitude 9° and 12° north and longitude 6° and 9° east. It covers an area of about 46,000 square kilometers. Kaduna city serves as the state capital and is one of the major commercial and industrial centers in northern Nigeria.

Study Design/ Sample Size

The study was a cross sectional and prospective type. Using a previous prevalence of 4%, Epi info 7 was used to calculate the sample size. A total of 185 HIV seropositive patients attending the clinic was gotten. Samples and questionnaires were administered and collected after a written consent was obtained.

Inclusion criteria

Confirmed HIV/AIDS adult patients attending HIV clinic

Exclusion criteria

HIV positive patients presenting with bloody diarrhoea

Questionnaire

An interviewer-based questionnaire was administered to every consenting participant, to get information on demography, exposure to the parasite and associated clinical symptoms.

Sample Collection And Processing

Participants were given labelled screw-capped plastic containers for the collection of the samples. They were also instructed on how to collect the sample without it getting contaminated with urine. The collected samples were preserved in 5% formalin and transported to the medical laboratory for analysis. A small portion of the stool sample was emulsified in 7mls of 10% formal saline solution in a centrifuge tube thoroughly. This was allowed to stand for 30 minutes for fixation. The faecal suspension was sieved, and 3ml of ether was added and shaken vigorously. The mixture was then centrifuged at 1000 rpm for 2 minutes. Using an applicator stick, the debris layer was loosened and, together with supernatant, was poured away. The sediment was re-suspended by tapping the bottom of the tube. A drop was placed on a glass slide and examined for other parasites before smears were made with sediment for *Cryptosporidium* oocyst. The smears were allowed to air dry before staining, protecting it from dust and flies.[13]

Modified Zeil Nelson Staining

After the adequate drying of smeared glass slides, the slides were fixed with 95% absolute methanol and stained using the modified Ziehl-Neelsen stain. This involved staining smears with concentrated carbol fuchsin and allowed to stand for 5 minutes, after which it was rinsed with clean tap water. The smear was decolourized with 1% hydrochloric acid (HCl) in 95% ethanol, rinsed off and counterstained with methylene blue for 2 minutes. The smear was, again, rinsed with clean tap water and air dried examined under oil immersion lens for the presence of Oocysts of *Cryptosporidium* (appeared as oval pinkish red on a blue background).[14]

Statistical Analysis

All statistical analyses were performed using SPSS version 24.0 at a 95% confidence level and probability value at ($P<0.005$). One-way ANOVA was used to determine parasite prevalence/ and chi-square test was used to determine the levels of association between the variables used in this study.

Ethical Consideration

Ethical approval was obtained from the Ministry of Health Ethical Committee, Kaduna State before the commencement of the study. Also, a written informed consent was sought from each individual participating in the study. Confidentiality of participants was ensured during and after the study. The study was carried out at no cost to the participants.

RESULTS

A total of 185 HIV-positive patients were recruited in the study. A greater proportion of participants in the study 84 (45.4%) were in the 26–35 however, 36–45 and 46–55-year age brackets, 16 and 6 (33.3%) had the highest risk of the infection respectively. There were more males 132 (71.4%) in the study though females had more infected participants 16 (30.2%). While, 119 (64.3%) participants had secondary school certificates, participants with no formal education 3 (60.0%) were more infected. Majority were married 130 (70.3%) out of which 44 (33.3%) were infected. Seventy-two (38.9%) of study participants were self-employed, but infection rate was more 13 (33.8%) among the unemployed (Table 1).

There were statistically significant associations between environmental factors such as Tap/Pipe-borne water, pit latrine and boiled water and *Cryptosporidium* infection (Table 2).

Among the risk factors examined, boiling of water (r = –0.161, p = 0.028) and contact with animals (r = 0.165, p = 0.025) were statistically significant at the 0.05 level, indicating that these two factors had meaningful correlations with *Cryptosporidium* infection. (Table 3)

Table 1. Socio -Demographic Characteristics of Study Participants (n=185)

Demographic factor	No. tested	No. Positi ve for *Cryptosporidium* (%)	χ^2	P-Value
Age group (years)			a	
16-25	25	7 (28.0)	0.978	0.913
26-35	84	22 (26.2)		
36-45	48	16 (33.3)		
46-55	18	6 (33.3)		
56-65	10	2 (20.0)		
Gender				
Male	132	38 (28.8)	0.036	0.059
Female	53	16 (30.2)		
Educational status				
Primary	36	10 (27.7)	2.594	0.466
Secondary	119	33 (27.7)		
Tertiary	25	8 (32.0)		
Informal	5	3 (60.0)		
Marital status				
Single	20	4 (20.0)	2.106	0.551
Married	130	44 (33.8)		
Divorced	13	4 (30.7)		
Widowed	22	2 (9.1)		
Occupation				
Civil servant	59	16 (27.1)	0.913	0.923
Self -employed	72	20 (27.7)		
Unemployed	39	13 (33.3)		
Retired	5	1 (20.0)		
Others	10	1 (10.0)		

Table 2 . Association between Environmental Risk Factors and Cryptosporidium Infection among HIV/AIDS Patients in the Study Location.

Variables	No Tested	No Positive for *Cryptosporidium* (%)	p-value	OD (95% C.L)
Sources of water				
Tap/Pipe -borne water	116	33 (28.5%)	0.042 *	1.75 (1.02 – 2.98)
Yes	33 (28.5%)			
No	83 (71.5%)			
Well water	69	20 (29.0%)	0.051	1.68 (0.99 – 2.85)
Yes	20 (29.0%)			
No	49 (71.0%)			
Boil water	185	11 (5.9%)	0.001 **	0.34 (0.18 – 0.66)
Yes	11 (5.9%)			
No	174 (94.1%)			
Type of toilet				
Pit latrine	147	43 (29.3%)	0.033 *	1.62 (1.04 – 2.52)
Yes	43 (29.3%)			
No	104 (70.7%)			
Water system	14	3(21.4%)	0.069	1.48 (0.87 – 2.52)
Yes	8 (33.3%)			
No	16 (66.7%)			
Open defecation	24	8 (33.3%)	0.284	0.74 (0.41 – 1.32)
Yes	3 (21.4%)			
No	11 (78.6%)			
Total	185			
Contact with animals	185	60 (32.4%)	0.517	1.89 (1.12 – 3.18)
Yes	60 (32.4%)			
No	125 (67.6%)			

Table 3 . Correlation between risk factors associated with presence of C ryptosporidium among HIV/AIDS positive patients in a Primary Health Centre in Northwestern Nigeria.

Risk factor and MZN	R-value	p-value
Source of water	0.021	0.775
Boil water	-0.161	0.028
Type of toilet	0.024	0.750
Contact with animals	0.165	0.025

r = correlation coefficient is significant at the 0.01 level, p -value is significant at the 0.05 level

DISCUSSION

Cryptosporidium species are intestinal parasites that infect both humans and animals; it causes cryptosporidiosis which usually results to diarrhoea especially among those with impaired immunity**.**

The prevalence of Cryptosporidiosis in this study was 54 (29.2%). This varies with findings in other parts of Nigeria and in other parts of the world. In Nigeria, the prevalence in this study was higher than 7.2% reported among 250 HIV patients in south-south Nigeria,[15] 19.8% among 400 HIV-infected adults [16] in the southeast, 4.8% prevalence in northwest Nigeria,[10] 16.8%, in FCT-Abuja,[17] and 19.0% in Kano and Kaduna North-west Nigeria [10] Also, this prevalence when compared to studies across Africa and the globe is higher than that reported in Ghana, who reported 6.2% *C. parvum* among 418 HIV infected patients.[9] Other studies among HIV individuals in Mozambique,[18] Kenya,[19] Thailand,[20] Iran,[21] and Ethiopia[22] have reported prevalence between 8.9% and 26.3%, which were lower than those obtained in the present study. However, 29.2% prevalence obtained in this study is lower when compared to some selected studies as reported by Okojokwu, *et al*., with a prevalence of (54.5%),[23] Oyakhire *et al*. reported 44.4% in Edo, South south-Nigeria.[24] In Ibadan, Southwest Nigeria, Bejide *et al*. reported a 40.0% prevalence among HIV/AIDS seropositive patients.[25] Similarly, a study by Anejo-Okpopi *et al*., in Jos North-central Nigeria reported a higher prevalence of *Cryptosporidiosis* among HIV infected adult patients attending Jos University Teaching Hospital.[26] Also, a closely related study conducted by Opoku *et al*., in Ghana reported a prevalence of 46% among HIV patients.[27] Several explanations may account for the varying prevalence recorded in various studies of the parasite. These include factors such as whether the study population had diarrhoea or not or whether participants were on highly active antiretroviral therapy, the diagnostic method used, the season of sampling and location of study, age, among others. It is also likely that the prevalence of *Cryptosporidium* infection may not depend on all these factors but some of them.

The age group most affected was 36-45 and 46-55 years 16 (33.3%) and 6 (33.3%) respectively. This corresponds with what Askira et al., reported who stated that age normally affects the prevalence of many diseases with the extremes of life (children and elderly people) being most affected.[16]

In this study, females had a slightly higher infection rate of 16 (30.2%) out of the 53 female participants than male with 38 (28.8%) out of 132 participants. This may be attributed to the fact that polygamous family settings are highly encouraged, in the study location thereby increasing the chances of more females acquiring opportunistic infection This is in agreement with studies carried out in Maiduguri with females 52% and males 48%.[28] This finding however is in contrast with the work of Muntaz *et al.* who reported higher prevalence in male than in female. The findings from this study shows that married participants had the highest prevalence, 44 (33.3%) of acquiring the infection. Such living arrangements increase crowding, shared sanitation, and water contamination risks. This is consonant with the report of Madukwe *et al*., in Nasarawa State, North-central, Nigeria,[29] but disagrees with Okezie *et al*. who reported a higher prevalence among the singles than married.[30]

Based on Educational status, participants with informal education had the highest prevalence, 3 (60.0%). This agrees with the report of Olawunmi *et al*., Jos, Plateau State, Nigeria.[31] This could be due to the fact that informal education often correlates with lower socio-economic status. These individuals may have fewer resources to maintain good hygiene or invest in safe water supplies. These findings were consistent with other findings and support the facts that *cryptosporidium* is more likely identified from low socioeconomic status that engage in trading and artisans and do not bother in their hygiene condition of their environment which is the common practice in the study area.32,[33]

Participants who depended on tap/pipe-borne water recorded an infection prevalence of 33 (28.5%), and this relationship was statistically significant (p = 0.042). Although tap water is generally considered safe, contamination can occur through broken pipelines, intermittent supply, or cross-contamination with sewage, especially in semi-urban communities. This aligns with findings by Salihu *et al*.,[5] who reported a higher rate of *Cryptosporidium* infection among individuals using municipal water systems than those using treated boreholes, citing poor maintenance and leakage as contamination routes. Similarly, Nwokediuko *et al.,* in Enugu observed that patients consuming untreated tap water had nearly double the odds of infection compared to those using bottled or filtered water.[8] Conversely, in a study in Namwala District, Zambia found no significant difference between water source and infection prevalence, attributing their results to widespread contamination across all water sources due to poor municipal infrastructure.[34]

In this study, participants who used well water had an infection prevalence of 20 (29.0%), which was borderline significant (p = 0.051, OR = 1.68; 95% CI: 0.99–2.85). Although the p-value was slightly above the conventional 0.05 threshold, the result still indicates a noteworthy trend, suggesting that reliance on well water may increase the likelihood of *Cryptosporidium* infection among HIV/AIDS patients. The relatively high prevalence among well-water users can be attributed to contamination from surface runoff, faecal seepage, and proximity of wells to pit latrines or refuse dumps, which are common in many semi-urban and rural Nigerian communities. This finding aligns closely with Chukwuma *et al*. in Ebonyi State, who observed a higher infection rate among respondents using shallow and uncovered wells compared to those using boreholes or treated water.[35] The authors attributed this to the infiltration of faecal matter and animal waste into groundwater sources, particularly during the rainy season. Similarly, a study in Ghana reported that *Cryptosporidium* oocysts were frequently detected in water samples drawn from domestic wells located near pit latrines, demonstrating the ease with which underground water sources can become contaminated.[36]

A strong, statistically significant association was observed between boiling water before drinking and *Cryptosporidium* infection (p = 0.001, OR = 0.34). Individuals who boiled their water had a much lower infection rate 11(5.9%) compared to those who did not. This finding is consistent with the results found in Maiduguri, who demonstrated that boiling water before consumption reduced *Cryptosporidium* infection risk by more than 60%.[28] Effective boiling of water inactivates oocysts of Cryptosporidium, which is cheaper than chlorination.[37]

The type of toilet used has shown a statistically significant association (p = 0.033), with those using pit latrines presentating with a higher infection rate 43 (29.3%) compared to individuals using water cistern toilets. Poorly maintained pit latrines can serve as sources of environmental contamination through surface runoff, flies, and groundwater seepage. This result agrees with Chukwuma *et al*., in Ebonyi, who reported that pit latrine users were nearly twice as likely to test positive for *Cryptosporidium* as those using water cistern toilets.[35] Similarly, a study in Abuja noted that infection rates were higher among households practicing open defecation or using traditional pit latrines without proper covers.[30] On the other hand, another study found no significant association between toilet type and infection in Enugu, suggesting that *Cryptosporidium* transmission may also occur through other channels, such as contaminated food or person-to-person contact.[31] Shared toilets have been reported to be associated with diarrhoea and other diseases in Nigeria and other parts of the world and are therefore classified as limited sanitation by the WHO/UNICEF-Joint Monitoring Program (JMP) for water supply and sanitation because of their unhygienic and poorly managed nature.[38]

However, these findings disagree with that reported in Ghana where it was found that participants who used public water closets were approximately 9 times more likely to be infected with *Cryptosporidium* than those who practiced open defecation.[9] It was further stated that the finding is quite surprising as the use of water closet is apparently more hygienic than the practice of open defecation. Even though the water closet is considered as an 'improved sanitation' facility, a general lack of cleanliness that characterizes most of the shared public toilet facilities may account for this observation.[9]

Although not statistically significant, open defecation and the use of water cistern toilets showed observable trends in infection rates. Open defecation recorded an infection prevalence of 8 (33.3%), higher than those who use pit latrine and water cistern toilet, reflecting the potential of environmental faecal contamination to facilitate oocyst transmission. The lack of statistical significance may be due to the relatively small sample size of individuals practicing open defecation. Nonetheless, Ojuromi *et al*., Nigeria[33] and Semmani *et al*., in Algeria[7] emphasized that open defecation remains an important indirect source of infection in resource-limited areas, as it increases contamination of surface and groundwater sources used for domestic purposes.

The study also revealed a strong and significant relationship between contact with animals and *Cryptosporidium* infection (p = 0.017, OR = 1.89*), denoting that individuals who handled or lived near animals had nearly twice the odds of infection compared to those without animal contact. This finding supports the zoonotic nature of *Cryptosporidium*, which can be transmitted from domestic or livestock to humans. Similar outcomes were reported by Yunusa *et al*. in Northwest Nigeria[39] and Sarfo *et al*. in Ghana Sub-Saharan African study,[36] both of which found strong associations between animal rearing and *Cryptosporidium* infection among HIV-positive patients. The likely transmission route involves contact with contaminated animal faeces or handling of unwashed vegetables grown near animal grazing areas. Conversely, Nyamwange *et al*., in Kenya reported no significant association, possibly due to low rates of domestic livestock ownership among their urban participants.[19] The correlation results demonstrate that behavioural factors (boiling of water and animal contact) exert greater influence on infection risk than structural environmental variables. This agrees with Ishar *et al*., and Ajayi *et al*., who both concluded that hygienic practices and personal exposure behaviours were stronger predictors of *Cryptosporidium* infection than socioeconomic status or sanitation type.[40,31] Differences between studies may stem from variations in climate, sample size, diagnostic sensitivity, and local infrastructure. For example, rural communities with frequent flooding or poorly drained soils may experience more environmental spread of oocysts, while urban areas face contamination through broken municipal pipes.

CONCLUSION

The findings in this study indicates that *Cryptosporidium* infection remains a significant opportunistic parasite contributing to morbidity among immunocompromised individuals in the region. Environmental and behavioural risk factors particularly the source of water, the type of toilet facility used, and contact with animals played an important role in infection transmission. Boiling of water before drinking proved to be a protective factor, highlighting the importance of hygienic water handling practices.

RECOMMENDATIONS

The study accentuates the need for improved environmental sanitation, regular monitoring of water quality, and community education on safe hygiene and water-use practices. Promoting preventive hygiene measures along with strengthening antiretroviral therapy adherence can significantly reduce the burden of *Cryptosporidium* infection among immunocompromised populations in Nigeria.

REFERENCES

1. Arias-Agudelo LM, Garcia-Montoya G, Cabarcas F, Galvan-Diaz AL, Alzate JF. Comparative genomic analysis of the principal Cryptosporidium species that infect humans. PeerJ. 2020 Dec 2;8:e10478. doi:10.7717/peerj.10478 PubMed PMID: 33344091. 06/05/2025
2. Bejide OS, Odebode MA, Ogunbosi BO, Adekanmbi O, Akande KO, Ilori T, et al. Diarrhoeal pathogens in the stools of children living with HIV in Ibadan, Nigeria. Front Cell Infect Microbiol. 2023 Mar 13;13:1–9. doi:10.3389/fcimb.2023.1108923
3. Iliyasu MY, Askira UM, Tom IM, Sahal MR, Dogonjeji SY, Tahir H, et al. Genotypic and Phylogenetic Profile of Cryptosporidium Parvum Strains from HIV Positive Patients in Maiduguri, Nigeria. International Journal of Pathogen Research. 2022 Jun 8;1–10. doi:10.9734/ijpr/2022/v9i430230
4. Dahal AS, Okolo OM, Daam K, Nanma D, Obishakin OF, Waziri HS, et al. Cryptosporidiosis among HIV/AIDS Patients with Diarrhoea and Associated Risk Factors in Jos, North-Central Nigeria. Journal of BioMedical Research and Clinical Practice. 2021 Jul 8;4(2):9–18. doi:10.46912/jbrcp.222
5. Salihu A, Jahun I, Olusegun Oyedeji D, Fajemisin W, Idogho O, Shehu S, et al. Ensuring equitable access to quality HIV care for affected populations in complex sociocultural settings: Lessons from Nigeria. PLoS One. 2025 May 14;20(5):e0319807. doi:10.1371/journal.pone.0319807
6. Guilavogui T, Gantois N, Desramaut J, Cissé FI, Touré SC, Kourouma BL, et al. *Cryptosporidium* spp. prevalence in the general population in Guinea: first large-scale screening study. Parasite. 2024 Nov 13;31:70. doi:10.1051/parasite/2024070
7. Semmani M, Costa D, Achour N, Cherchar M, Ziane H, Mouhajir A, et al. Occurrence and Molecular Characterization of Cryptosporidium Infection in HIV/Aids Patients in Algeria. Viruses. 2023 Jan 27;15(2):362. doi:10.3390/v15020362
8. Nwokediuko S, Ijoma U, Obienu O, Young E, Anigbo G, Onyia C, et al. Defecation frequency and stool form in rural and urban african settings. Nigerian Journal of Gastroenterology and Hepatology. 2020 May 22;11(2):56. doi:10.4103/NJGH.NJGH_2_20
9. Dankwa K, Nuvor SV, Obiri-Yeboah D, Feglo PK, Mutocheluh M. Occurrence of Cryptosporidium Infection and Associated Risk Factors among HIV-Infected Patients Attending ART Clinics in the Central Region of Ghana. Trop Med Infect Dis. 2021 Dec 9;6(4):210. doi:10.3390/tropicalmed6040210
10. Muhammad AB, Kumurya AS. Sero-Prevalence of Cryptosporidiosis among People Living with HIV/AIDS in North-western Nigeria. Bayero Journal of Nursing and Health Care. 2023 Oct 16;5(1):1197–205. doi:10.4314/bjnhc.v5i1.18
11. Karshima SN, Karshima MN. Epidemiology of Cryptosporidium Infections among People Living with HIV/AIDS in Nigeria: Results of Systematic Review and Meta-analysis. Acta Parasitol. 2021 Mar 1;66(1):60–74. doi:10.1007/S11686-020-00253-8 PubMed PMID: 32683583.
12. Erhabor O, Obunge O, Awah I. Cryptosporidiosis among HIV-infected persons in the Niger Delta of Nigeria. Niger J Med. 20(3):372–5. PubMed PMID: 21970221.
13. Tahvildar-biderouni F, Salehi N. Detection of Cryptosporidium infection by modified ziehl-neelsen and PCR methods in children with diarrheal samples in pediatric hospitals in Tehran. Vol. 7. 2014;7(4):125–30.
14. Clarke SC, McIntyre M. Acid-fast bodies in faecal smears stained by the modified Ziehl-Neelsen technique. Br J Biomed Sci. 2001;58(1):7–10. PubMed PMID: 11284227.
15. Solomon NU, Ifeoma ME, Godsplan U, John I, Aghanya N, Simon NU, et al. Epidemiology of

Cryptosporidiosis in HIV Positive Patients Treated in Major Tertiary/Secondary Hospitals in Rivers State, Southern Nigeria. Journal of Biomedical Investigation. 2023;11(2):2–12.
16. Askira UM, Iliyasu MY, Tom I. M, Al-hassan A., Dogonjeji S.Y, Panda SM, et al. Cryptosporidium parvum Co-infection in Respect to CD4+ T-Lymphocyte Count of HIV/AIDS Patients Receiving Antiretroviral Therapy at Umaru Shehu Ultra-Modern Hospital Maiduguri, Nigeria. G. Balint, Antala B, Carty C, Mabieme JMA, Amar IB, Kaplanova A, editors. South Asian Journal of Parasitology. 2022 May 5;7(1):1–11. doi:10.2/JQUERY.MIN.JS PubMed PMID: 25246403.
17. Abdulkadir A, Umut G, Aysegul OT. Prevalence of intestinal parasitosis and immunological status of HIV/AIDS patients on antiretroviral therapy in Nyanya General Hospital, Abuja, Nigeria. . Vol. 17. 2022;17(4).
18. Squire SA, Ryan U. *Cryptosporidium* and Giardia in Africa: current and future challenges. Parasit Vectors. 2017;10(1):195. doi:10.1186/s13071-017-2111-y
19. Nyamwange C, Mkoji G.M, Mpoke S. Cryptosporidiosis among HIV positive patients in the North Rift region of Kenya. Afr J Health Sci. 2012;21(2):92–106.
20. Wang ZD, Liu Q, Liu HH, Li S, Zhang L, Zhao YK, et al. Prevalence of *Cryptosporidium*, microsporidia and Isospora infection in HIV-infected people: A global systematic review and meta-analysis. Parasit Vectors. 2018;11(1):1–19. doi:10.1186/s13071-017-2558-x
21. Ghafari R, Rafiei A, Tavalla M, Moradi Choghakabodi P, Nashibi R, Rafiei R. Prevalence of *Cryptosporidium species* isolated from HIV /AIDS patients in southwest of Iran. Comp Immunol Microbiol Infect Dis. 2018;56:39–44. doi:10.1016/j.cimid.2017.12.002 PubMed PMID: 29406282.
22. Adamu H, Wegayehu T, Petros B. High prevalence of diarrhoegenic intestinal parasite infections among non-ART HIV patients in Fitche Hospital, Ethiopia. PLoS One. 2013;8(8):e72634. doi:10.1371/journal.pone.0072634 PubMed PMID: 23991132.
23. Okojokwu OJ, Inabo HI, Yakubu SE, Okubanjo OO, Akpakpan EE, Kolawole T, et al. Molecular characterisation of *Cryptosporidium species* among patients presenting with diarrhoea in some parts of Kaduna State, Nigeria. . American Journal of Research Communication . 2016;4(3):87–106.
24. Akinbo FO, Okaka ChristopherE, Omoregie R. Prevalence of intestinal parasitic infections among HIV patients in Benin City, Nigeria. Libyan Journal of Medicine. 2010 Jan 29;5(1):5506. doi:10.3402/ljm.v5i0.5506
25. Bejide OS, Odebode MA, Ogunbosi BO, Adekanmbi O, Akande KO, Ilori T, et al. Diarrhoeal pathogens in the stools of children living with HIV in Ibadan, Nigeria. Front Cell Infect Microbiol. 2023 Mar 13;13. doi:10.3389/fcimb.2023.1108923
26. Anejo-Okopi JA, Okojokwu JO, Ebonyi AO, Ejeliogu EU, Isa SE, Audu O, et al. Molecular characterization of *Cryptosporidium* in children aged 0-5 years with diarrhea in Jos, Nigeria. doi:10.11604/pamj.2016.25.253.10018
27. Opoku YK, Boampong JN, Ayi I, Kwakye-Nuako G, Obiri-Yeboah D, Koranteng H, et al. Socio-Behavioral Risk Factors Associated with Cryptosporidiosis in HIV/AIDS Patients Visiting the HIV Referral Clinic at Cape Coast Teaching Hospital, Ghana. Open AIDS J. 2018 Sep 12;12(1):106–16. doi:10.2174/1874613601812010106
28. M. Umoru A, Samaila AB, Panda SM, Iliyasu MY, Kadaura UM, Umar MA, et al. Prevalence of Cryptosporidiosis Detected by Enzyme Immunoassay Coproantigen among People Living with HIV/AIDS Attending Selected Hospitals in Maiduguri, Nigeria. Int J Trop Dis Health. 2021 Oct 9;42(14):17–25. doi:10.9734/ijtdh/2021/v42i1430513
29. Madukwe HA, Gyar SD, Ekeleme IK. Prevalence of *Cryptosporidium* oocyts, amongst human immunodeficiency virus patients attending selected hospitals in Nasarawa State, Nigeria. Open Access Research Journal of Science and Technology. 2025 May 30;14(1):001–8. doi:10.53022/oarjst.2025.14.1.0056
30. Okezie Gabriel Chidiebere, Nwobu R, Mgbowula GI. Prevalence Of Intestinal Parasitic InfectionAmong Clients Attending Private MedicalLaboratory Diagnostic Center In Karshi,Abuja,North Central Nigeria. British Journal of Medical & Health Science. 2020;2(12):2–6.
31. Olawunmi Toyin Ajayi, Olufunmilola Bamidele Makanjuola, Adebola Temitope Olayinka, Abdulhakeem Olorukooba, Josephine Ene Olofu, Patrick Nguku, et al. Predictors of intestinal parasite infection among HIV patients on antiretroviral therapy in Jos, Plateau State, Nigeria . Pan African Medical Journal. 2021;38(306).
32. Ngutor S. Occurrence of Cryptosporidium species and other zoonotic parasites among humans in Jos, Plateau State, North-Central Nigeria.
33. Ojuromi OT, Opedun D.O, Uhoegbu OU, lbidapo C. Concurrent intestinal parasitoses with *Cryptosporidium species* among patients with gastrointestinal disorder in Lagos, Nigeria. UNILAG Journal of Medicine, Science and Technology. 2019;1(1):17–23.
34. Sinyangwe NN, Siwila J, Muma JB, Chola M, Michelo C. Factors Associated With *Cryptosporidium* Infection Among Adult HIV Positive Population in Contact With Livestock in Namwala District, Zambia. Front Public Health. 2020 Mar 13;8. doi:10.3389/fpubh.2020.00074
35. Chukwuma Chrysanthus. *Cryptosporidium*: Public Health Problems and Environmental Indicators. Austin Medical Sciences. 2019;4(2).
36. Sarfo FS, Frickmann H, Dompreh A, Osei Asibey S, Boateng R, Weinreich F, et al. High Clinical Burden of *Cryptosporidium spp.* in Adult Patients with

Acquired Immunodeficiency in Ghana. Microorganisms. 2024 Oct 26;12(11):2151. doi:10.3390/microorganisms12112151

37. Omolabi KF, Odeniran PO, Soliman ME. A meta-analysis of *Cryptosporidium species* in humans from southern Africa (2000–2020). Journal of Parasitic Diseases. 2022 Mar 18;46(1):304–16. doi:10.1007/s12639-021-01436-4
38. WHO. Sanitation [Internet]. 2025 [cited 2026 Feb 23]. Available from: https://www.who.int/publications/m/item/state-of-systems-for-drinking-water--sanitation-and-hygiene--global-update-2025
39. Yunusa T, Kolade Yunusa HO. Prevalence of Cryptosporidiosis among HIV Seropositive Patients in a Tertiary Health Institution , Nigeria. J Med Dent Sci. 2015;14(5):16–24. doi:10.9790/0853-14541624
40. Ishar CO, Mbaawuaga EM, Ikeh MI, Okeke OA, Benedict AG, Nnatuanya IO, et al. Cryptosporidium infection among HIV positive and HIV negative out-patients attending selected HIV care hospitals in Gboko, Benue state, Nigeria. Journal of Current Biomedical Research. 2024 Jun 30;4(3):1628–43. doi:10.54117/jcbr.v4i3.3