A ‘One Health’ perspective of Africa-wide distribution and prevalence of Giardia species in humans, animals and waterbodies: a systematic review and meta-analysis

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Abstract

Giardiasis, caused by *Giardia duodenalis*, is a leading cause of diarrhoea in resource-poor countries. To gain a better insight into the epidemiology of *Giardia* in Africa, we undertook a robust study to comprehend the distribution and prevalence of *Giardia* infection in humans, animals and their dispersal in the environment. Our protocol was registered with PROSPERO (registration number CRD42022317653). Deep literature search from 5 electronic databases, namely, AJOL, Google scholar, PubMed, ScienceDirect and Springer Link was performed using relevant keywords. Meta-analysis was performed using a random-effects model and heterogeneity among studies was evaluated using Cochran’s Q and the *I²*-statistic. More than 500 eligible studies published from 1 January 1980 until 22 March 2022 were retrieved. In humans, exactly 48 124 *Giardia* spp. infection cases were registered from the 494 014 stool samples examined resulting in a pooled prevalence estimate (PPE) of 8.8% using microscopy. Whereas copro-antigen tests and molecular diagnostic methods generated PPE of 14.3 and 19.5%, respectively, with HIV+ subjects and those with diarrhoeatic stool having infection rates of 5.0 and 12.3%, respectively. The PPE of *Giardia* spp. infection in animals using molecular methods was 15.6%, which was most prevalent in pigs (25.2%) with Nigeria registering the highest prevalence at 20.1%. The PPE of *Giardia* spp. contamination from waterbodies was 11.9% from a total of 7950 samples which were detected using microscopy, with Tunisia documenting the highest infection rate of 37.3%. This meta-analysis highlights the necessity of ‘One Health’ approach for consolidated epidemiological studies and control of giardiasis in the African continent.

Introduction

*Giardia* (Metamonada, Giardiidae) is an enteric flagellated diplomonad protozoan parasite that infects a wide range of mammalian hosts including humans and animals, leading to one of the most frequently occurring parasitic diseases known as giardiasis (Xu et al., 2020). The infection can be asymptomatic in some cases, and when symptoms do appear, they can range from persistent diarrhoea, abdominal pain, by severe malabsorption, all of which can have a negative influence on growth and intellectual development (Ramirez et al., 2015). This protist is ubiquitously distributed and is responsible for cases of human diarrhoea annually, mostly in children <5 years of age with lower prevalence in developed compared to developing countries (Feng and Xiao, 2011; Mahdavi et al., 2022) and can infect over 40 animal species (Thompson and Monis, 2004; Taghipour et al., 2022). Life cycle of *G. duodenalis* begins when the infective cyst forms are shed into the environment in faecal material; excystation occurs which is enhanced by the gastric acid and pancreatic enzymes after ingestion by another host forming 2 motile pear-shaped trophozoites that subsequently colonize the small intestine (duodenum and jejunum) provoking conjugation and lipid metabolism dysfunction (Li et al., 2017; Buret et al., 2020).

Ingestion of cysts from polluted water or food causes infection in humans and other mammals (House et al., 2011). Transmission of this parasite is direct via the fecal–oral route, as in the case of farmers, veterinarians and petting zoos, or indirectly, as in polluted surface water or foods (Hunter and Thompson, 2005; Dixon et al., 2011). Water sources infected with cysts from fecal deposition or sewage disposal techniques are the most common sources of *Giardia* infection in humans (Solarczyk et al., 2021). Dogs and cats that are kept as pets could also serve as major zoonotic transmission route to humans (Aw et al., 2019).

 Globally, the detection, identification and characterization of *Giardia* are central to investigating and understanding the epidemiology of giardiasis. Diagnostic methods that have been employed broadly include fecal microscopy, immunodiagnostics and molecular techniques (Hooshyar et al., 2019).

Giardiasis has been included in the Neglected Disease Initiatives of the World Health Organization (WHO) since September 2004 due to its health effects on children and pregnant women as well as being associated with poverty (Mirrezaie et al., 2019). The incidence of *Giardia* in the resource-poor countries is estimated to be 20–30% due to hazardous water
supplies, sanitation and hygiene (Groudan et al., 2021). In sub-Saharan Africa and West Africa, prevalences are estimated to be 7.36 and 8.97%, respectively (Bogoch et al., 2006; Belhassen-Garcia et al., 2017). We performed a systematic review and meta-analysis using a ‘One Health’ approach in order to better define the prevalence and epidemiological distribution of *Giardia* species in animals, humans and waterbodies from published literature between 1980 and 2022 in the African continent. We are of the opinion that the outcomes of this study will be useful to policy makers on how to minimize the burden of giardiasis in developing countries.

**Materials and methods**

**Protocol and registration**

The protocol for this study was preregistered in PROSPERO with registration number CRD42022317653. We performed a systematic review and meta-analysis following the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines (Page et al., 2021) which have been confirmed on a checklist (Supplementary Table S1).

**Search strategy**

Literature searches were conducted using keywords (Table 1) on PubMed, ScienceDirect, AJOL, SpringerLink and Google Scholar on articles published in English language from 1 January 1980 until 22 March 2022 for articles with emphasis on the prevalence or epidemiology of *Giardia* species across the continent of Africa in animals, humans and waterbodies. None of the authors of original studies were contacted for additional information and no attempt was made to retrieve unpublished articles. Titles and abstracts were scanned, and relevant full-text articles were downloaded and obtained through library resources and online platforms.

**Eligibility criteria**

**Inclusion and exclusion criteria**

Articles were included only if they fulfilled the following inclusion criteria: cross-sectional (prevalence) study conducted within African continent; study involving the detection and/or screening of vertebrate hosts (humans or animals), waterbodies including fecal and water samples for *Giardia duodenalis* (syn. *G. intestinalis, G. lamblia*); the exact total numbers and positive cases were clearly provided; sample size (>50 to enable statistical computations); published study written in English language; study conducted between 1 January 1980 until 22 March 2022. Studies were excluded if (i) they were conducted outside of Africa, (ii) case control or randomized studies, (iii) involved the detection of *Giardia* in fresh produce or soil, (iv) incomplete data on the total number of samples screened or number of positives obtained, (v) published papers outside the study periods and (vi) written in other languages.

**Study selection and data extraction**

Independent reviewers (M. T. and T. O.) carefully evaluated all titles and abstracts identified in the search, as well as full texts considered to be relevant. Any disagreements were resolved by discussion with the other 2 authors (T. R. and O. T.). Titles and abstracts derived through primary electronic search were thoroughly assessed for possibility of inclusion based on the study type (prevalence of *Giardia* in animals, humans and waterbodies), and duplicates were removed. Full texts were examined and unrelated studies were excluded with reasons. All studies that met the eligibility criteria were included for syntheses. From each eligible study, the following data were extracted and organized using Microsoft Excel spreadsheet using the format of the author and countries, study/publication year, country, hosts, total sample size, number of positive cases, estimated prevalence, consistency of the feces and different diagnostic technique. Studies that were conducted in more than 1 country and those that had both animal, human and waterbodies studies simultaneously were separated accordingly.

**Quality assessment of included studies/risk of bias**

The risk of bias for each study was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Tools for cross-sectional study (Munn et al., 2015). This JBI instrument consists of 9 criteria, of which details are available (Supplementary Table S2). Each response to the individual criteria was assigned a score of 0 or 1 for no or yes answers. When the question was not applicable to the study, not applicable (NA) was used. A maximum score of 9 was possible but only 8 was applicable to our kind of study that was eligible for incorporation in this review. Studies with scores of 7–8 indicated a low risk of bias, scores of 5–6 indicated a moderate risk of bias, and scores less than 5 indicated a high risk of bias.

**Data synthesis**

The current meta-analysis was conducted using the Comprehensive Meta-Analysis software (CMA) version 3.0 software (Borenstein et al., 2014). The pooled prevalence estimates (PE) and 95% confidence interval (CI) were calculated using random-effects models. Statistical heterogeneity between studies was measured by *I*² statistic (Higgins et al., 2003). Publication bias was measured using funnel plots to test for symmetry and this was further complimented using the Begg’s and Mazumdar rank (BMR) correlation test (Begg and Mazumdar, 1994).

**Results**

**Search results**

A total of 6222 studies were retrieved following the initial search from 5 databases (Fig. 1). A total of 2242 articles were removed as follows: (i) they were conducted outside of Africa, (ii) case control or randomized studies, (iii) involved the detection of *Giardia* in fresh produce or soil, (iv) incomplete data on the total number of samples screened or number of positives obtained, (v) published papers outside the study periods and (vi) written in other languages.
they were duplicates and the remaining articles \((n = 3980)\) were screened based on titles and abstracts. Thereafter, a total of 3270 was removed as unlikely leaving 710 studies that were subjected for eligibility and were thus examined by full-text evaluation. Exactly 206 articles were excluded with reasons as follows: studies conducted outside of Africa \((n = 97)\), studies with no clarity on data \((n = 66)\), studies with focus on animal experiment \((n = 21)\) and lastly, studies with different types of samples \((n = 22)\). Ultimately, for the quantitative synthesis (meta-analysis) of eligible studies, a total of 426, 67 and 24 studies were used for human, animal and waterbodies, respectively, to obtain the PPE (Fig. 1).

**General characteristics of the included studies**

The characteristics of all eligible studies included in this review are presented in Supplementary Tables S3–S5. All studies were published from 1980 to 2022, with the majority of the studies conducted in the last 2 decades (2002–2022). The prevalence for all the individual studies was computed and presented in Supplementary Table S1. All studies were conducted in different parts of Africa, with eligible studies with focus on humans widely distributed across the continent in different countries. Exactly 34 countries documented the existence of *Giardia* species in samples collected from humans with Ethiopia \((n = 115)\) having the highest number of studies, followed by Nigeria and Egypt with 53 studies each. Others include Kenya \((n = 31)\), Ghana \((n = 26)\), Guinea \((n = 15)\) and South Africa \((n = 14)\). Details of the findings from other countries are presented in Fig. 1. For studies pertaining to animals, Uganda \((n = 11)\) and Nigeria \((n = 9)\) had high number of eligible studies. Lastly, both Egypt and South Africa had 6 published eligible studies with interest on *Giardia* species from samples collected from waterbodies. Diagnostic technique employed across the 3 (human, animals and waterbodies) different subjects of interest includes microscopy, copro-antigen tests and molecular-based diagnostics.

**Quality assessment of included studies**

The quality assessment score of included studies ranged from 7 to 8 as per JBL critical appraisal checklist for studies reporting *Giardia* spp. prevalence data. About 10, 6 and 11 studies were excluded from this systematic review and meta-analysis for humans, animals and waterbodies, respectively, since they scored less than 66.7%.

**PPE of *G. duodenalis* infection in humans**

Different diagnostic methods were utilized for the detection of *Giardia* spp. infections from stool samples collected from humans across the continent. Of the 494 014 stool samples examined for *Giardia* spp. infection, 48 124 cases were registered as positives using microscopy. Thus, the PPE was 8.8% (95% CI 8.0–9.6%) (Table 2). Using copro-antigen tests, the PPE of anti-*Giardia* spp. was 14.3% (95% CI 10.1–20.0%). Lastly, a total of 16 095 stool samples were examined for the prevalence of *Giardia* spp. infection using molecular-based methods, out of which 2437 samples were positive with PPE of 19.5% (95% CI 13.0–24.3%) (Table 2). According to gender, the PPE in males was 13.3% (95% CI 11.7–15.1%) compared to 11.9% (95% CI 10.3–13.8%) in females. Furthermore, *G. duodenalis* infections were more prevalent in human subjects within the age range 0–18 years with PPE of 13.4% (95% CI 10.9–16.4%) while those within 19–35 years had the least PPE of 8.8% (95% CI 7.1–10.8%). The

![Figure 1. PRISMA flow chart.](https://doi.org/10.1017/S0031182023000513)
Table 2. Sub-group analysis of *Giardia duodenalis* infection in human subjects across Africa

<table>
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<th>Sample size</th>
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<th>Pooled prevalence estimates</th>
<th>Measure of heterogeneity</th>
<th>Publication bias</th>
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<td>54 160</td>
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<td>58 365</td>
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<td>&gt; 36</td>
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<td>11 465</td>
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<td>2011–2022</td>
<td>197</td>
<td>202 130</td>
<td>26 492</td>
<td>9.6 (8.6–10.6)</td>
<td>11 666.71</td>
<td>98.32</td>
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<td>76 656</td>
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<td>12.3 (10.3–14.7)</td>
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<td>23 863</td>
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<td>9.7 (7.2–12.9)</td>
<td>4433.19</td>
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<td>Algeria</td>
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<td>9733</td>
<td>1504</td>
<td>16.7 (9.1–28.7)</td>
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<td>Angola</td>
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<tr>
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<td>Egypt</td>
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<td>30 220</td>
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<td>15.3 (5.4–36.6)</td>
<td>20.59</td>
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<td>6.4 (4.0–10.2)</td>
<td>1521.33</td>
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<td>Lesotho</td>
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<td>98</td>
<td>12.9 (5.9–26.0)</td>
<td>33.42</td>
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(Continued)
PPE in human subjects in rural areas was 17.9% (95% CI 13.0–24.3%) comparatively higher to human subjects in urban areas 9.2% (95% CI 6.3–13.1%) (Table 2). Additionally, the PPE of giardiasis was notably observed in the 1981–1990 year interval at 11.4% (95% CI 7.5–17.0%), followed by 9.6% (95% CI 7.4–12.3%) in 2001–2010, 9.6% (95% CI 8.6–10.6%) in 2011–2022 and 7.9% (95% CI 5.4–11.6%) in 1990–2000 year interval (Table 2). Human subjects that were HIV+ had a higher PPE of giardiasis at 5.0% (95% CI 3.5–7.3%) compared to those who were HIV− at 4.1% (95% CI 2.5–6.6%). Based on stool consistency, patients with diarrhoeic stool had a higher PPE (12.3%; 10.3–14.7%) compared to non-diarrhoeic patients (9.7%; 7.2–12.9%). Finally, the PPEs at country level indicate that Tunisia registered the highest at 39.9% (with only 2 eligible studies) while the lowest PPE was registered in Cameroon 1.3% (95% CI 0.4–4.1%) (Table 2).

**PPE of G. duodenalis infection in animals**

Just like in human subjects, 3 diagnostic techniques were utilized in the detection of *Giardia* spp. infection in humans. Of the 12,873 fecal samples screened from animals using microscopy, a total of 856 were positive with PPE at 5.8% (95% CI 4.4–7.6%) (Table 3). Using serology, 789 samples were positive to anti-*Giardia* spp. out of a total of 3,896 samples screened with an estimated PP at 17.7% (95% CI 10.7–27.7%) (Table 3). From a total of 5,515 samples, 922 were positive for *Giardia* spp. infections using molecular methods with a PPE of 15.6% (95% CI 9.4–24.9%) (Table 3). According to study year, *Giardia* spp. infections were more prevalent in the 2011–2022 year interval with PPE of 16.2% (95% CI 11.0–23.3%), followed by 8.9% (95% CI 5.7–13.6) in 2001–2010, and then 2.6% (95% CI 1.0–6.9%) in 1990–2000 year interval (Table 3). Based on animal host, pigs had the highest PPE of 25.2% (95% CI 9.7–51.6%) followed by goats of 18.9% (95% CI 11.5–29.4) and the lowest was observed in monkeys of 5.3% (95% CI 0.8–28.0%) (Table 3). The PPE according to country level indicates that Nigeria had the highest at 20.1% (95% CI 10.8–34.1%) and Rwanda with the lowest at 4.3% (95% CI 2.9–6.3%) (Table 3).

**PPE of G. duodenalis contamination in waterbodies**

A total of 7,950 samples from various waterbodies across the continent were examined for the prevalence of *Giardia* spp. contamination, out of which 1,407 water samples were positive using microscopy with PPE of 11.9% (95% CI 7.7–18.0%) (Table 4). Furthermore, of the 1,288 water samples examined for the prevalence of *Giardia* spp. contamination, a total of 454 samples were positive using molecular methods, with PPE of 32.0% (95% CI 24.7–40.2%). The *Giardia* parasite was most prevalent in the 2011–2022 year interval, with PPE of 25.3% (95% CI 13.8–41.6%) as compared to 2001–2010 year interval with 8.9% (95% CI 2.6–26.8%). Finally, based on country distribution, Tunisia registered the highest PPE at 37.3% while the lowest was observed in Nigeria at 15.4% (95% CI 6.2–33.5%) (Table 4).

**Risk of publication bias of included studies**

The funnel plots of the estimates suggested publication bias (Supplementary Figs S1–S8) for both human studies with asymmetric presentations and BMR test values observed with respect to human studies were microscopy method (P = 0.000), males (P = 0.004), females (P = 0.008), 2011–2022 year interval (P = 0.000), HIV+ (P = 0.004), HIV− (P = 0.007), diarrhoeic (P = 0.001),
Cameroon ($P = 0.014$), Ethiopia ($P = 0.000$), Nigeria ($P = 0.000$) and Sudan ($P = 0.025$). Whereas for animals, observed publication bias was on 2001–2010 year interval ($P = 0.040$), cattle ($P = 0.009$) and Ethiopia ($P = 0.019$) (Tables 3 and 4 and Supplementary Figs S9–S11). However, Funnel plots and BMR tests suggested no publication bias for waterbody studies (Fig. 2).

**Discussion**

Herein, we carried out a robust study to investigate the epidemiology and occurrence of *Giardia* species in humans, animals and from waterbodies across Africa using over 500 published articles that employ different diagnostic methods including microscopy, copro-antigen and molecular-based techniques. Arising from differences in the sensitivity and specificity of the diagnostic methods employed in the investigation of the prevalence of giardiasis, we observed varying prevalence rates (Hooshyar et al., 2019). Light microscopy is regarded as the gold standard method recommended for the diagnosis of cystic and/or trophozoite stages of *G. duodenalis* (Soares and Tasca, 2016). Several factors including number of fecal samples and operator experience examined may affect the outcome of investigation of giardiasis using this approach as opined by Elmi et al. (2017) and David and AP (2006) leading to lower prevalence of infection or complete failure of detection (Taghipour et al., 2022). There is an increased utilization of immunodiagnostic techniques to complement fecal microscopy for giardiasis detection and appears to be reliable for confirmatory diagnosis (Hooshyar et al., 2019). On the other hand, DNA-based molecular methods are also reported to be more reliable with appropriate sensitivity for the identification of *Giardia* species (Thompson and Monis, 2004; Gelanew et al., 2007).

**Giardia species infection in humans**

The total PPE of *Giardia* parasite infections in humans was higher using molecular techniques (19.5%) as compared to...
microscopic (8.8%) and copro-antigen (14.3%), a finding that is similar to that documented in Ghana and Spain, respectively, where molecular tests (6.6 and 37.5%) detected more *Giardia* spp.-positive infections than microscopy (1.0 and 4.1%) and copro-antigen (5.6 and 4.1%) (Anim-Baidoo et al., 2016; Alharbi et al., 2020). However, Al-Shehri et al. (2016) in Uganda (41.6; 19.3; 0%), Gasparinho et al. (2017) in Angola (18.8; 4.1; 0.5%) and Jelinek and Neifer (2013) in Germany (51.1; 50.0; 46.6%) reported that serological tests detected more positives as compared to microscopic and molecular techniques in that order. Whereas in Gambia, Goudal et al. (2019) and Sullivan et al. (1991) reported that microscopy (20.1 and 48.6%) detected more *Giardia* spp.-positive infections as compared to serological tests (18.5 and 30.6%) in that order respectively. Furthermore, Emisiko et al. (2020) in Kenya (46.5; 13.0%), Geus et al. (2019) in Rwanda (36.0; 7.1%) and El Fatni et al. (2014) in Morocco (12.5; 3.0%) reported that microscopy detected more *Giardia* spp.-positive infections as compared to molecular methods. Remarkably, Becker et al. (2015) reported similar detection prevalence (28.7%) by microscopy, copro-antigen and molecular methods in Côte d’Ivoire. Van den Bossche et al. (2015) (4.1; 4.1%) in Belgium and Doni et al. (2013) (19.6; 19.6%) in Turkey reported equal prevalence on microscopic and copro-antigen methods and Irisarri-Gutiérrez et al. (2017) in Mozambique (6.1; 7.1%) and El-Badry et al. (2017) in Egypt (11.0; 11.9%) reported microscopic and copro-antigen methods to have similarly equal results towards molecular methods, respectively. This difference can be accounted by differences in specificity and sensitivity of detection techniques used and our review showed that prevalences generally are higher when molecular detection methods are used compared to microscopic or copro-antigen tests, suggesting that molecular tests have a higher sensitivity.

Country-specific findings indicate that Tunisia had the highest PPE of 39.9% for *Giardia* spp. infections, with the rural populations (17.9%) being more susceptible as compared to the population in urban regions (9.2%). This observation is similar to that reported by Díaz et al. (2015) in Peru (53.1% rural; 40.6% urban).
urban), El Fatni et al. (2014) in Morocco (19.6% rural; 7.6% urban), Cervantes Gracia et al. (2017) in Mexico (22.3% rural; 17.9% urban), Heimer et al. (2015) in Rwanda (43.9% rural; 8.7% urban) and Lobo et al. (2014) in DR Congo (18.7% rural; 1.9% urban). In contrast, Huot et al. (2016) and Loewenson et al. (1986) reported higher prevalence of Giardia parasite infections in peri-urban regions (12.3%; 22.3%) as compared to rural regions (7.2%; 15.6%) in Cambodia and Zimbabwe in that order respectively. However, Ahmad et al. (2020), Berrilli et al. (2006), Ngonjo et al. (2015) and Roche and Benito (1999) reported similar Giardia spp. prevalence between urban (20.8%; 44; 6.9; 7.2%) and rural (21.6; 44; 7.4; 8.6%) area populations in Egypt, Albania, Kenya and Guinea-Bissau, respectively. About 40.0% of the population in Africa resides in urban areas and thus, anthropogenic activities might be responsible for this observation. Furthermore, the wide variety of socio-economic, climate and geographical characteristics might have influenced this geographical difference in Giardia species prevalence (Ahmed et al., 2018). The infection was higher in male (13.3%) subjects compared to females (11.9%). Similarly, Abdel-Aziz et al. (2020) reported higher Giardia infection prevalence than non-diarrhoeal individuals (9.7%). Our findings agree with the report from Algeria (14.6 and 0.3%), India (16.0 and 8.0%), Libya (26.3 and 0.0%) and Madagascar (12.6 and 7.7%) where diarrhoeic individuals had higher Giardia parasite infection prevalence as compared to non-diarrhoeal individuals (Dwivedi et al., 2007). In contrast, Bodhidatta et al. (2010), Haque et al. (2005), Messa et al. (2021) and Tellekve et al. (2015) found that Giardia spp. prevalence was higher in non-diarrhoeal (10.0; 18.0; 32.0; 6.1%) as compared to diarrhoeal (6.0; 7.7; 20.0; 3.4%) individuals in Thailand, Bangladesh, Mozambique and Tanzania, respectively. However, some studies reported similarly equal prevalence on diarrhoea and non-diarrhoea in DRC (2.3 and 1.7%) and Nigeria (0.5 and 0.0%), respectively (Ogunsanya et al., 1994; Wumba et al., 2010). These differences can be attributed to variable immune responses of individuals.

Giardia spp. infection in animals

This study has recorded PPE of 17.7% for detection of Giardia infections in animals using serological technique which is higher than microscopy and molecular methods. Fayer et al. (2012) reported a higher prevalence of 51.1% using molecular technique compared to microscopic methods (19.2%) in the USA. Furthermore, the study by Wang et al. (2018) found that both serology (5.8%) and molecular (5.2%) methods had similarly higher detection performance as compared to microscopy (3.7%) for detection of Giardia spp. infections in China. On the contrary, Bouzid et al. (2015) reported higher Giardia spp. infections by microscopy (53.3%) in comparison to molecular (9.2%) and serological methods (26.6%) in Norwich and UK. This difference in diagnostic methods might be due to individual assay sensitivity and less expertise in microscopy.

The subgroup analysis at the country level showed that the PPE of Giardia spp. in different African countries ranged from 4.3 to 20.1% with the highest from Nigeria and lowest in Rwanda. These differences might be due to sample size, methodology used to detect and number of studies included in the current study. Animal species were grouped into domestic (cats, cattle, dogs, goats, pigs and sheep) and wildlife (baboos, baboons, buffaloes, bushbuck, chimpanzees, grasscutter, gorillas, guenons, lions, Maxweil’s duiker, monkeys, rabbit, rat, royal antelopes and wild dogs) with each group prevalence pooled together. Our subgroup analysis also revealed that wildlife had lower PPE as compared to domestic animals. However, Castro-Hermida et al. (2011) reported wildlife as the main source of exposure for the transmission of Giardia parasite to domestic animals, humans, as well as contamination of waterbodies. Our study witnessed a 13.6% increase in the continent PPE of Giardia pathogen in animals during the period of 1990–2022. However, periodic analysis revealed a 6.3% initial increase between 1990–2000 and 2001–2010 intervals which was followed by a continuous increase of 7.3% during the 2001–2010 and 2011–2022 intervals. This continuous increase of Giardia pathogens might be attributed to failure of animal disease control programmes across the African continent and the use of more advanced diagnostic techniques as years go by.
which is mainly at livestock African rural communities practice extensive communal farming spp. in rural settlements. It is well known that majority of waterbodies, will provide a clear understanding of the key routes wildlife, as well as the environment (Wang large numbers in humans, NHPs, domestic animals, pet animals, bodies. For instance, in China, domestic and wild animals, as well as the integrity status of water- link of the pathogen with human health, the health of both demiology of giardiasis as our study has highlighted the intricate significance of animals, hence, the prevalence in non-human primates (NHPs), domestic animals, Malawi, Mali, Mauritania, Mauritius, Morocco, Niger, Sao Tome and Principe, Seychelles, Sierra Leone, Somalia, South Sudan, Sudan, Togo, Tunisia and Zimbabwe.

In studies involving waterbodies, only 1 study was included in the year 1980 until 2000 and no data were available in countries such as Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Central African Republic, Chad, Comoros, Congo, Djibouti, Equatorial Guinea, Eritrea, Esatvini, Gambia, Guinea, Lesotho Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Namibia, Niger, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Sudan, Sudan, Togo and Zambia. Finally, we recommend that future studies should be directed to investigation of the epidemiology of this protozoan parasite in countries where surveillance is low as this parasite may pose dan- ger to animals and citizens of those countries.

### Supplementary material.
The supplementary material for this article can be found at https://doi.org/10.1017/S0031182023000513.

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