

Review Article

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Epidemiology of gastrointestinal nematodes of free-ranging chickens (*Gallus gallus domesticus*) in Africa: A systematic review and meta-analysis

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Abstract

A systematic review and meta-analysis were conducted, and published estimates determined the pooled prevalence of gastrointestinal nematode parasites affecting free-ranging chickens in Africa. Peer-reviewed articles published between 1993 and 2024 were systematically searched and screened. Prevalence estimates based on 76 eligible articles showed that of the 74,789 free-ranging chickens screened, 13,625 were infected with gastrointestinal nematodes with an overall pooled prevalence of 15% (95% CI: 13–18%). Twenty-seven nematode species were recorded, of which *Ascaridia galli* and *Heterakis gallinarum* were the commonly reported species. Southern Africa recorded the highest pooled prevalence (22%; 95% CI: 13–33%), and western Africa had the lowest (5%; 95% CI: 0–2%) despite recording the highest nematode species diversity. Tetrameridae had the highest family-level pooled prevalence of 46% (95% CI: 28–64%), and Spiruridae had the lowest 1% (95% CI: 0–3%). Most studies were conducted between the period 2014 and 2024; however, the highest pooled prevalence was observed between 1993 and 2002 (17%; 95% CI: 11–24%). The necropsy technique recorded the highest pooled prevalence (17%; 95% CI: 14–20%) compared to coproscopy (10%; 95% CI: 7–14%). The quality effects model revealed a high heterogeneity and publication bias among studies due to the diagnostic method used ($P < 0.05$). This systematic review provided insightful information on the occurrence and potential burden of gastrointestinal nematode species of free-ranging chickens in Africa, highlighting the need for enhanced biosecurity and further research to safeguard their health, production, and food security of rural economies.

Introduction

Chicken (*Gallus gallus domesticus*) is one of the most intensively reared domesticated poultry species, and a fundamental and profitable animal production enterprise (Guèye 2003; FAO 2004). This industry significantly contributes to food security, poverty reduction, and ecological utilisation of natural resources, particularly for smallholder farmers in rural and peri-urban areas (Guèye 2003; Mapiye et al. 2008). In 2022, Africa's total poultry population was estimated at 2,425 million, of which 2,352 million were chickens (FAOSTAT 2024). Among domestic birds kept for meat and egg production, free-ranging village chickens are the predominant species in the rural poultry sector, where they are raised by village communities for subsistence (Malatji et al. 2016; Muchadeyi et al. 2004), with a large proportion kept under a traditional free-range production system.

According to Sarba et al. (2019), free-range chickens contribute over 70% of poultry products and 20% of animal protein intake in Africa. These chickens mainly constitute indigenous breeds, primarily reared successfully in resource-limited rural villages of developing countries due to their adaptation to harsh environmental conditions and extensive husbandry practices (Elson et al. 2011). They scavenge during the day whilst occasionally being fed leftover scrap food and/or rationed formulated chicken feed and are confined to shelters at night (Muchadeyi et al. 2009). This husbandry system predisposes them to various diseases as they feed and attain food from contaminated environments (Mukaratirwa et al. 2001; Permin and Pedersen 2002) and their associated intermediate hosts (Phiri et al. 2007). Several studies have shown that free-ranging chickens are often affected by several bacterial, viral, fungal, and parasitic infections, resulting in reduced production, high morbidity, mortality, and subsequent significant economic losses (Irungu et al. 2004; Kaingu et al. 2010; Ola-Fadunsin et al. 2019). Parasitic infections rank high among these infections, and gastrointestinal helminths (cestodes, nematodes, and trematodes) are the most prevalent parasites affecting poultry production (Berhe et al. 2019; Mikail and Adamu 2008; Mohammed et al. 2021; Muhairwa et al. 2007; Mukaratirwa et al. 2001; Mungube et al. 2008; Ngongeh et al. 2012).

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In Africa, the prevalence of gastrointestinal helminths in free-ranging chickens is influenced by a combination of environmental, management, and host-related factors (Shiferaw et al. 2016). The warm and humid climates prevalent in many regions of the continent provide ideal conditions for the survival and transmission of helminth parasites (Mungube et al. 2008). Numerous studies have reported on gastrointestinal helminth parasites, including cestodes and nematodes (Mwale and Masika 2011); however, nematodes are considered the most significant due to their high species diversity, wide geographical distribution, and the extent of pathological effects they cause in chickens (Shiferaw et al. 2016).

Nematodes affecting free-ranging chickens have been reported in several continents including Asia (Butt et al. 2015; Das et al. 2020; Ebrahimi et al. 2014; Nik Nur et al. 2015; Salam 2015; Vijayalingam et al. 2023; Win et al. 2020; Wuthijaree et al. 2019), Oceania (Shifaw et al. 2023), North America (Carrisoza et al. 2021; Cervantes-Rivera et al. 2016; Cornell et al. 2022), South America (da Silva et al. 2018; Saraiva et al. 2021) and in Africa (Berhe et al. 2019; Jinga et al. 2012; Magwisha et al. 2002; Maina et al. 2017; Mukaratirwa and Khumalo 2010; Mukaratirwa et al. 2001; Mungube et al. 2008).

To date, 19 nematode genera have been reported to affect free-range chickens in Africa and these include *Ascaridia* Dujardin 1845, *Heterakis* Schrank 1790, *Capillaria* Zeder 1800, *Eucoleus* Dujardin 1845, *Baruscapillaria* Moravec 1982, *Aonchotheca* López Neyra 1947, *Tetrameres* Creplin 1846, *Strongyloides* Grassi 1879, *Subulura* Molin 1860, *Dispharynx* Chabaud 1975, *Cheilospirura* Diesing 1861, *Gongylonema* Molin 1857, *Syngamus* Siebold 1836, *Cyathostoma* Blanchard 1849, *Oxyspirura* Drasche in Stossich 1898, *Trichuris* Roederer 1761, *Hartertia* Seurat 1915, *Skrijabinocerca* Schikhobalova 1930, and *Trichostrongylus* Looss 1905 (Magwisha et al. 2002; Mukaratirwa and Khumalo 2010; Mukaratirwa et al. 2001; Nghonjuyi et al. 2014; Offiong et al. 2013; Permin et al. 1997; Poulsen et al. 2000; Tay et al. 2017). High prevalence of infections has been reported from the following species: *Ascaridia* (A.) *galli*, *Heterakis* (H.) *gallinarum*, and *Capillaria* spp. (Jinga et al. 2012; Shiferaw et al. 2016; Wuthijaree et al. 2019), where pathology was predominant in juvenile birds with an underdeveloped immune system (Urquhart et al. 1996), while heavy infestations in adults allowed them to serve as reservoirs of infection (Permin et al. 1997).

Despite the widespread occurrence of gastrointestinal nematodes in free-ranging chickens across Africa, there is limited comprehensive data on their overall prevalence and distribution. Existing studies often focus on specific regions or countries, making it difficult to draw a unified picture of the impact of gastrointestinal nematodes affecting free-range chicken production across the continent (Phiri et al. 2007). Therefore, understanding the epidemiology of gastrointestinal nematodes is crucial for the development of sustainable and cost-effective control strategies tailored to the unique conditions of African poultry farming systems (Dube et al. 2010). This review, therefore, aims to provide a comprehensive overview of the prevalence of gastrointestinal nematodes in free-ranging chickens across Africa from 1993 to 2024 through a systematic review and meta-analysis.

Methods

Search strategy

A systematic search of the literature was conducted on Google Scholar, PubMed, and Web of Science databases to retrieve studies reporting on gastrointestinal nematodes of free-ranging

chickens from 1993 to 2024. The search combined the following predetermined search terms and Boolean operators (AND, OR): gastrointestinal (GIT) nematode parasites OR GIT worms OR GIT nematode OR GIT parasitic infections AND prevalence AND free-ranging chickens in African countries. Further relevant studies were identified by cross-referencing or screening through bibliographies of relevant articles. Full-text articles were retrieved and managed on EndNote reference manager version X8 (Clarivate Analytics, Philadelphia, PA, USA).

Selection criteria

Articles were included if they met the following predetermined criteria during appraisal for meta-analysis: (i) peer-reviewed studies conducted in Africa and published between 1993 and 2024, (ii) studies conducted specifically on free-ranging chickens, (iii) the number of free-ranging chickens surveyed and infected by GIT nematodes were clearly stated for prevalence calculation, (iv) GIT nematodes were identified up to species level, (v) the diagnostic/detection method(s) used were clearly stated. Studies were excluded if they reported on GIT nematodes of other poultry species or of intensively reared chickens, were conducted outside Africa, were not conducted within the time frame, were published in languages other than English, and lacked sufficient information or relevant outcomes.

Data extraction

Literature search and selection were conducted by I.W.; then M.M.P. and I.N. independently checked selected articles and confirmed the extracted data. Thereafter, duplicates and articles that did not meet the inclusion criteria were excluded from analysis. Relevant information, such as the author's names, year of publication, country of study, number of free-range chickens screened, number of positive cases and prevalence, nematode species detected, and the diagnostic method used, was extracted from text, tables, and figures and computed on MS Excel for meta-analysis.

Quality assessment of the articles

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach was used to assess the overall quality of each article for meta-analysis (Guyatt et al. 2008). Studies were allocated a one-point score for each inclusion criterion met; therefore, each study received a score ranging from 0 to 5 points. Publications were deemed of good quality if they received a total score of 5 points, moderate quality a score of 4, and low quality a score of ≤ 3 , and all articles with a low quality score were excluded from the study (Doi and Thalib, 2008). The standardized quality index score (between 0 and 1) was then computed by calculating scores using five domains: reporting clarity, locality, diagnostic validation, sample size, and sampling strategy. The total score was calculated by adding the points from each domain, with higher scores indicating a lower risk of bias.

Meta-analysis and meta-regression

To avoid overestimating the weight of individual studies, the prevalence data were transformed using the double arcsine approach (Barendregt et al. 2013). This approach uses the arcsine transformation twice to measure the prevalence to account for any

heterogeneity which may be caused by extremely large or small sample sizes. The MetaXL add-in for Microsoft Excel was used to compute a quality effects model to account for any heterogeneity. Heterogeneity between estimates was evaluated using the inverse variance statistic (I^2 index), and its significance was assessed using Cochrane's Q test. The I^2 score of 25%, 50%, or 75% was interpreted as low, moderate, or high heterogeneity following Higgins et al. (2003) protocol, respectively. The estimated prevalence and the 95% confidence interval (CI) of the nematode species among the free-range chickens were graphically demonstrated on forest plots. Sources of variability in prevalence estimates were examined using a multivariate random-effects meta-regression in R Studio with the metafor package. Multivariate meta-regression was employed to assess the collective and individual effects of all predefined study-level characteristics simultaneously, while accounting for potential confounding among moderators. The meta-regression was treated as linear model on the logit-transformed prevalence data. The linear regression analysis was conducted to

evaluate publication bias, and the funnel plots were used to visualize the publication bias.

Results

Eligibility of search results

A literature search yielded 1701 records, and 1613 articles were excluded due to duplications or deemed ineligible based on their title and abstract (Fig. 1). Full-texts of 88 articles were retrieved and assessed for eligibility based on the predetermined inclusion criteria, and 12 studies were ineligible. Thus, the remaining 76 articles met the inclusion criteria for review and meta-analysis. These were distributed across 17 African countries from five regions, of which West Africa (Ghana and Nigeria) contributed more studies ($n = 28$), followed by East Africa (Eritrea, Ethiopia, Kenya, and Tanzania) ($n = 27$), Southern Africa (Botswana, Lesotho, South Africa, Zambia, and Zimbabwe) and North Africa

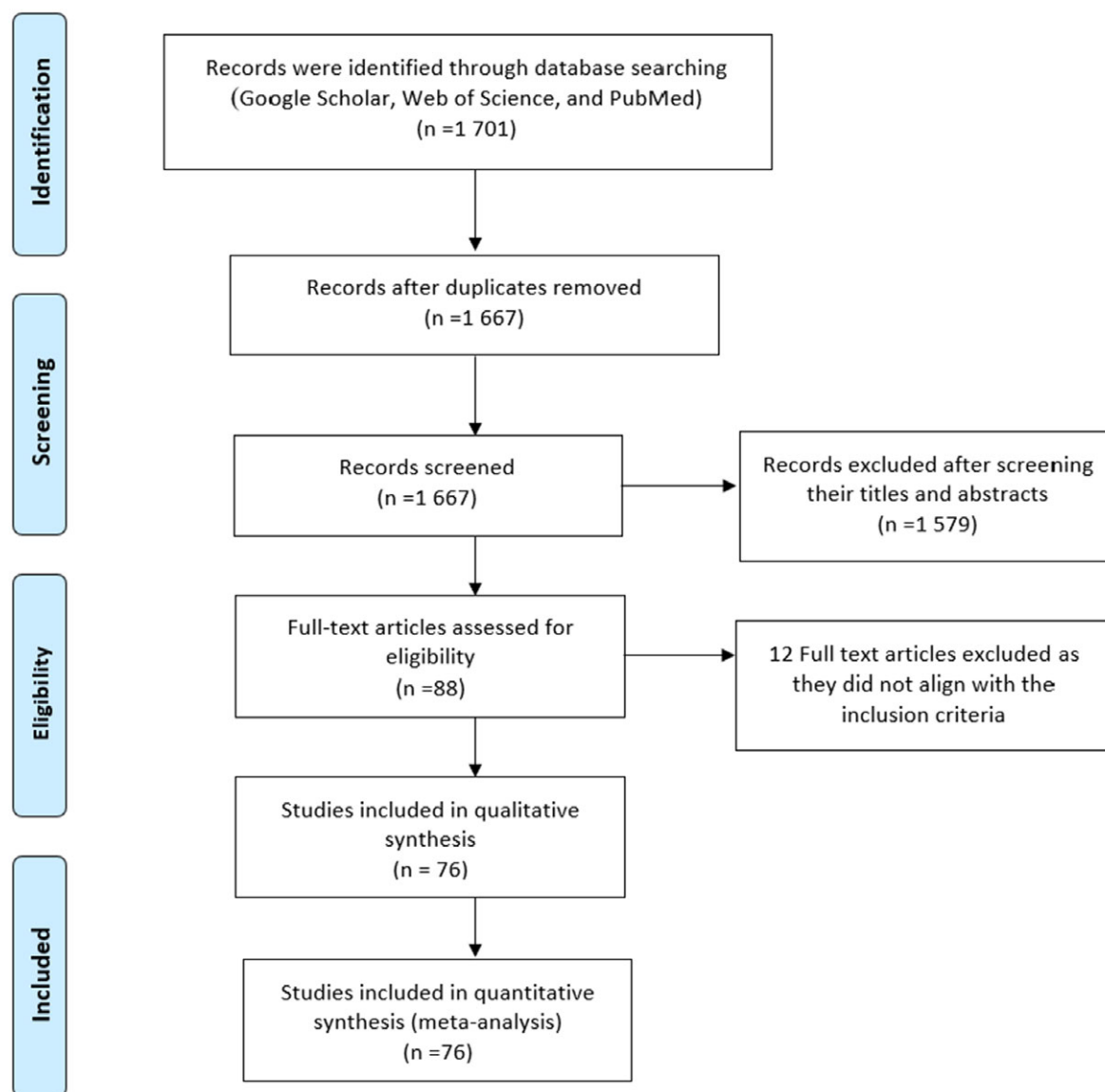


Figure 1. PRISMA flow diagram showing the search and selection process.

(Algeria, Egypt, Libya, Morocco, and Tunisia) both with 10 studies each, and the least studies were from Central Africa (Cameroon) ($n = 1$) (Supplementary Table S1).

Overall prevalence of gastrointestinal nematode species of free-range chickens

The frequency of nematode species affecting free-range chickens is presented in Table 1. Out of a total of 74 789 free-ranging chickens screened, 13 625 were infected with one or more GIT nematode species, and the overall pooled prevalence was 15% (95% CI: 13–18%) (Supplementary Table S1). A total of 27 nematode species were documented, and *A. galli* and *H. gallinarum* were the most recorded nematode species, with the former reported in all 76 studies and the latter reported in 68 studies. The highest prevalence of 100% was reported with *Baruscapillaria* (*B.*) *obsignata* in Zimbabwe, and the lowest prevalence of 0.2% was reported with *B.*

Table 1. Frequency of nematode species affecting free-ranging chickens from 1993 to 2024

Nematode species	No. of studies	No. examined	No. infected	Prevalence (%)
<i>Anchotheca bursata</i>	2	800	73	9.1
<i>Anchotheca caudinflata</i>	4	1094	87	8.0
<i>Ascaridia columbae</i>	1	175	3	1.7
<i>Ascaridia galli</i>	76	16,157	4425	27.4
<i>Baruscapillaria obsignata</i>	12	2835	418	14.7
<i>Capillaria anatis</i>	6	1357	227	16.7
<i>Cheilospirocha hamulosa</i>	14	2381	272	11.4
<i>Dispharynx nasuta</i>	11	2675	189	7.1
<i>Eucoleus annulatus</i>	9	2712	148	5.5
<i>Eucoleus contortus</i>	7	1784	102	5.7
<i>Eucoleus retusus</i>	1	710	37	5.2
<i>Gongylonema congolense</i>	1	200	81	40.5
<i>Gongylonema ingluvicola</i>	17	2628	604	23.0
<i>Hartertia gallinarum</i>	3	302	3	1.0
<i>Heterakis beramporia</i>	1	42	4	9.5
<i>Heterakis brevispiculum</i>	2	400	63	15.8
<i>Heterakis dispar</i>	4	879	117	13.3
<i>Heterakis gallinarum</i>	68	14,575	3471	23.8
<i>Heterakis isolonche</i>	9	1544	335	21.7
<i>Oxyspirocha mansonii</i>	1	35	2	5.7
<i>Strongyloides avium</i>	13	3496	194	5.6
<i>Subulura brumpti</i>	30	5981	1135	19.0
<i>Subulura strongylina</i>	2	708	23	3.3
<i>Syngamus trachea</i>	19	5604	169	3.0
<i>Tetrameres americana</i>	12	2149	1099	51.1
<i>Tetrameres fissispina</i>	3	489	149	30.5
<i>Trichostrongylus tenuis</i>	10	3077	195	6.3
Total		74,789	13,625	14.3

obsignata in Lesotho and *Syngamus* (*S.*) *trachea* in Nigeria and Kenya, with 0.2% and 0.3%, respectively. The quality effects model revealed a significantly high degree of heterogeneity between studies ($Q = 19\ 756.59$, $P < 0.01$), with an I^2 index of 98%.

Prevalence of nematode infections in free-ranging chickens by region

Southern African region recorded the highest pooled prevalence of GIT nematode infections in free-ranging chickens 22% (95% CI: 13–33%) (Fig. 2), followed by eastern Africa with 16% (95% CI: 13–20%) (Fig. 3), northern African region with 14% (95% CI: 9–21%) (Fig. 4), central Africa with 12% (95% CI: 8–17%) (Fig. 5), and western Africa recorded the least pooled prevalence of 5% (95% CI: 0–2) (Fig. 6). Western Africa had the highest species diversity ($n = 23$) and central Africa had the least ($n = 2$). The quality effects model revealed a significantly high degree of heterogeneity between regions, with eastern and southern Africa recording the highest heterogeneity ($I^2 = 99\%$, $P < 0.01$) (Fig. 2 and 3), followed by western Africa ($I^2 = 97\%$, $P < 0.01$) (Fig. 6), northern Africa ($I^2 = 96\%$, $P < 0.01$) (Fig. 4), and central Africa ($I^2 = 88\%$, $P < 0.01$) (Fig. 5).

Prevalence of gastrointestinal nematodes at family level

The prevalence of nematodes affecting free-range chickens was computed according to their families (Table 2), and the Tetrameridae family recorded the highest overall pooled prevalence of 46% (95% CI: 28–64%), while Syngamidae and Spiruridae families recorded the lowest pooled prevalence of 2% (95% CI: 1–4%) and 1% (95% CI: 0–3%), respectively. However, these families had low species diversity, with the Tetrameridae family consisting of two species, *Tetrameres* (*T.*) *americana* and *T. fissispina*, and the former species recorded the highest prevalence of 51.1% (Table 1). Syngamidae and Spiruridae families had one representative species each, *S. trachea* and *Hartertia* (*Ha.*) *gallinarum*, respectively. Results from the quality effects model across all nematode families revealed a high heterogeneity of $I^2 > 80\%$ ($P < 0.01$), except for Spiruridae family, which recorded $I^2 = 0\%$ ($P > 0.01$) (Table 2). It was not possible to conduct a meta-analysis for the family Thelaziidae due to the limited number of studies.

Prevalence of gastrointestinal nematode species in free-range chickens by time in years

Variation in the prevalence of gastrointestinal nematode species in free-range chickens was evaluated according to eras, and articles were divided into three groups: 1993–2002, 2003–2013, and 2014–2024. Results showed that most studies were conducted between 2014 and 2024, and the least between 1993 and 2002. Species diversity corresponded with the frequency of studies available, with the highest diversity noted during the period of 2014–2024, followed by 2003–2013, and the least during 1993–2002. However, the pooled prevalence of gastrointestinal nematode species in free-range chickens was highest during the era 1993–2002 (17%; 95% CI: 11–24%), followed by 2003–2013 and 2014–2024 (with 14%; 95% CI: 10–19% and 14%; 95% CI: 11–17%, respectively). Results from the quality effects model revealed a high heterogeneity in reports of GIT nematodes in free-range chickens over time, with all eras recording $I^2 > 95\%$ ($P < 0.01$) (Table 3).

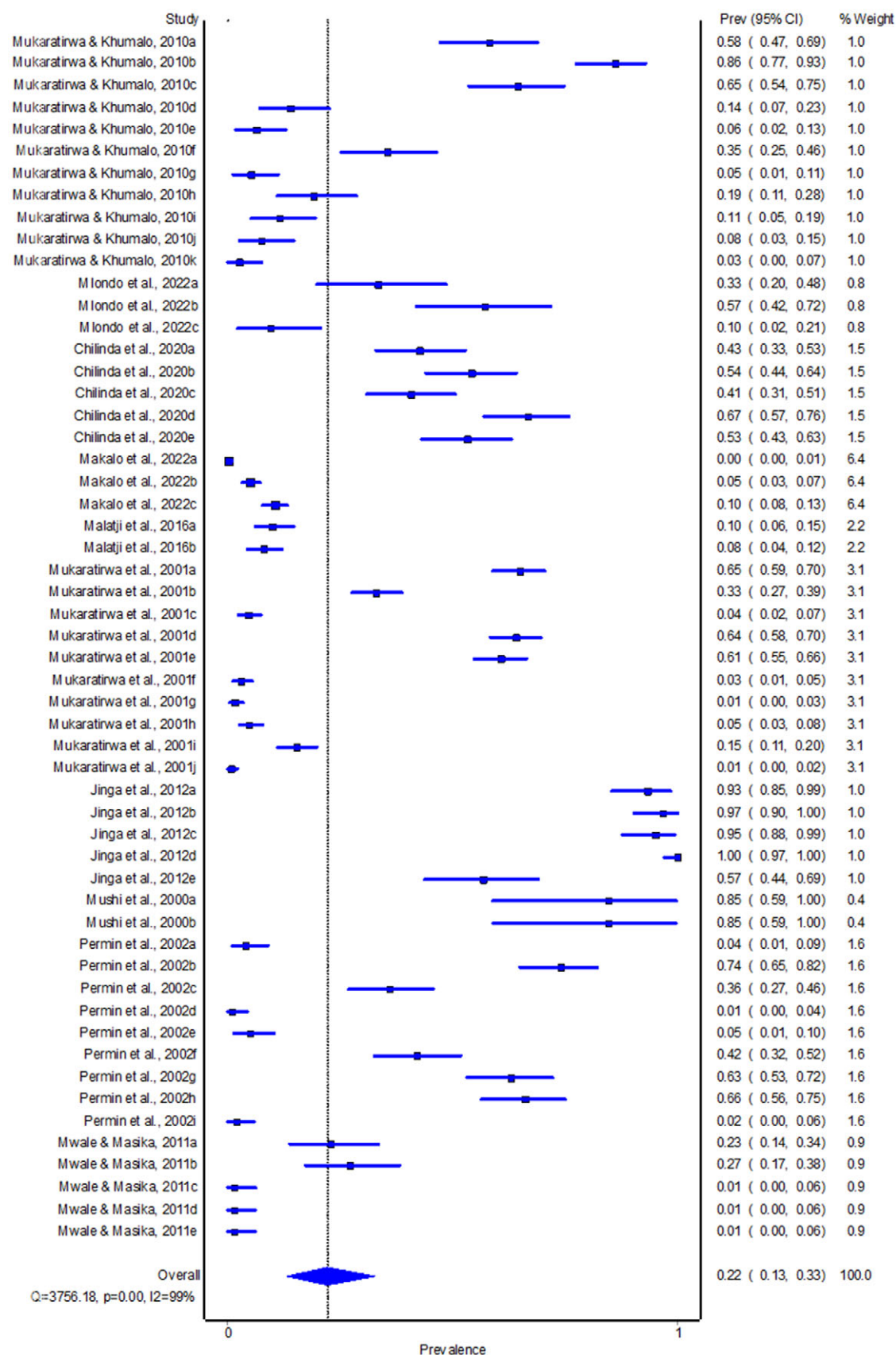


Figure 2. Forest plot for the prevalence of gastrointestinal nematode species in free-range chickens from Southern Africa from 1993 to 2024.

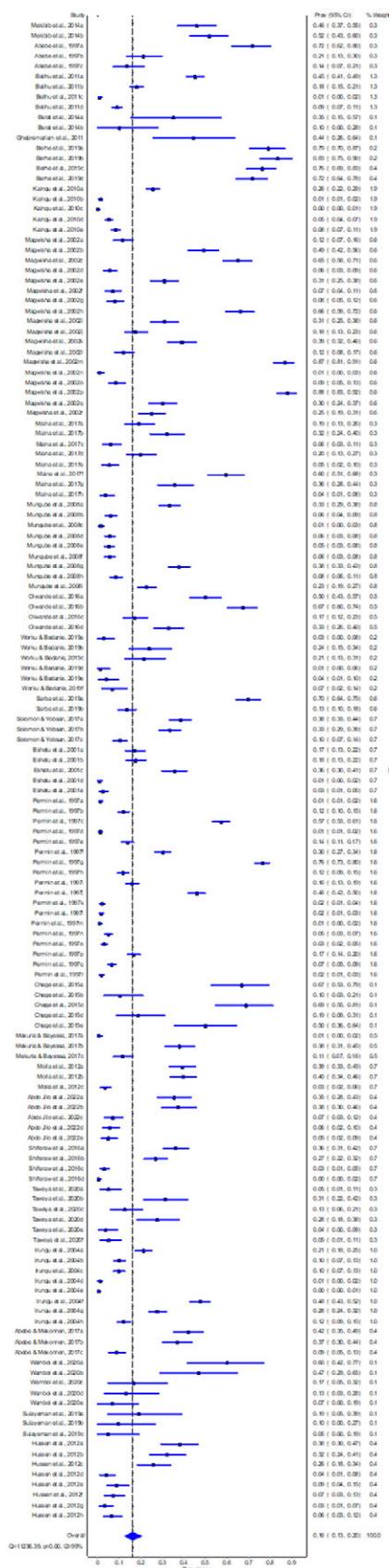


Figure 3. Forest plot for the prevalence of gastrointestinal nematode species in free-range chickens from Eastern Africa from 1993 to 2024.

Prevalence of gastrointestinal nematodes in the free-range chickens by diagnostic/detection methods

To detect the infections of the gastrointestinal nematodes in the free-range chickens, three diagnostic techniques were used individually or in combination, viz necropsy, coproscopy, and molecular (PCR). Results showed that most studies used necropsy ($n = 48$) to detect infections, while 27 studies used coproscopy, 4 studies used a combination of necropsy and molecular (Table 3), and only one study used combined coproscopy and molecular methods and was not included in the meta-analysis. The pooled prevalence of gastrointestinal nematodes in free-range chickens based on techniques was higher with necropsy, with 17% (95% CI: 14–20%), followed by necropsy and molecular, with 15% (95% CI: 3–33%), and lastly coproscopy with 10% (95% CI: 7–14%) (Table 3). Results revealed a high heterogeneity between necropsy and coproscopy, both with $I^2 = 98\%$ ($P < 0.01$), and necropsy and molecular $I^2 = 92\%$ ($P < 0.01$) (Table 3).

Prevalence of gastrointestinal nematode species in free-range chickens by sex, age, and mixed infections

The prevalence of GIT nematode species in free-range chickens was evaluated according to sex, age, and mixed infections. Seven studies reported on the infection of the nematode species with regard to sex of the chickens, three on age, and six on mixed infections (Table 3; Fig. 7). The pooled prevalence of GIT nematodes in free-range chickens based on sex was higher in females (46%; 95% CI: 27–66%) compared to males (45%; 95% CI: 30–60%). Heterogeneity was high for both sexes ($I^2 > 90\%$, $P < 0.01$) (Table 3) and young (≤ 18 weeks) free-range chickens recorded a higher pooled prevalence of GIT nematodes (45%; 95% CI: 21–71%) compared to adults (> 18 weeks) (42%; 95% CI: 14–72%). However, a high heterogeneity was recorded in adult free-ranging chickens ($I^2 = 98\%$, $P < 0.01$) compared to the one recorded for the young ones ($I^2 = 96\%$, $P < 0.01$) (Table 3). Pooled prevalence for mixed infections of GIT nematode species in free-range chickens recorded 11% (95% CI: 6–18%), and a relatively average heterogeneity of $I^2 = 72\%$ ($P < 0.01$) (Fig. 7).

Publication bias and multiple linear regression

Asymmetric funnel plots were observed, indicating the presence of publication bias (Supplementary Figure S1), which may be due to a small-sample-size bias or publication bias in the articles. The multivariate meta-regression model, incorporating region, parasite family, study period, and diagnostic method, provided a statistically significant fit to the data (QM = 194.57, df = 4, $P < 0.0001$). This confirms that the selected moderators collectively have a significant effect on the observed prevalence estimates. The meta-regression analysis revealed that several nematode families were significantly associated with higher effect sizes, including Ascaridiidae (estimate = 2.08, $P < 0.001$), Heterakidae (estimate = 1.56, $P < 0.001$), and Tetrameridae (estimate = 2.14, $P < 0.001$), while Gongylonematidae and Subuluridae showed weaker but significant positive associations. Among diagnostic methods, necropsy alone yielded a significant positive effect (estimate = 0.57, $p = 0.004$), whereas coproscopy-based methods did not significantly influence the estimates. No significant differences were observed across study periods or African regions (Supplementary Table S2).

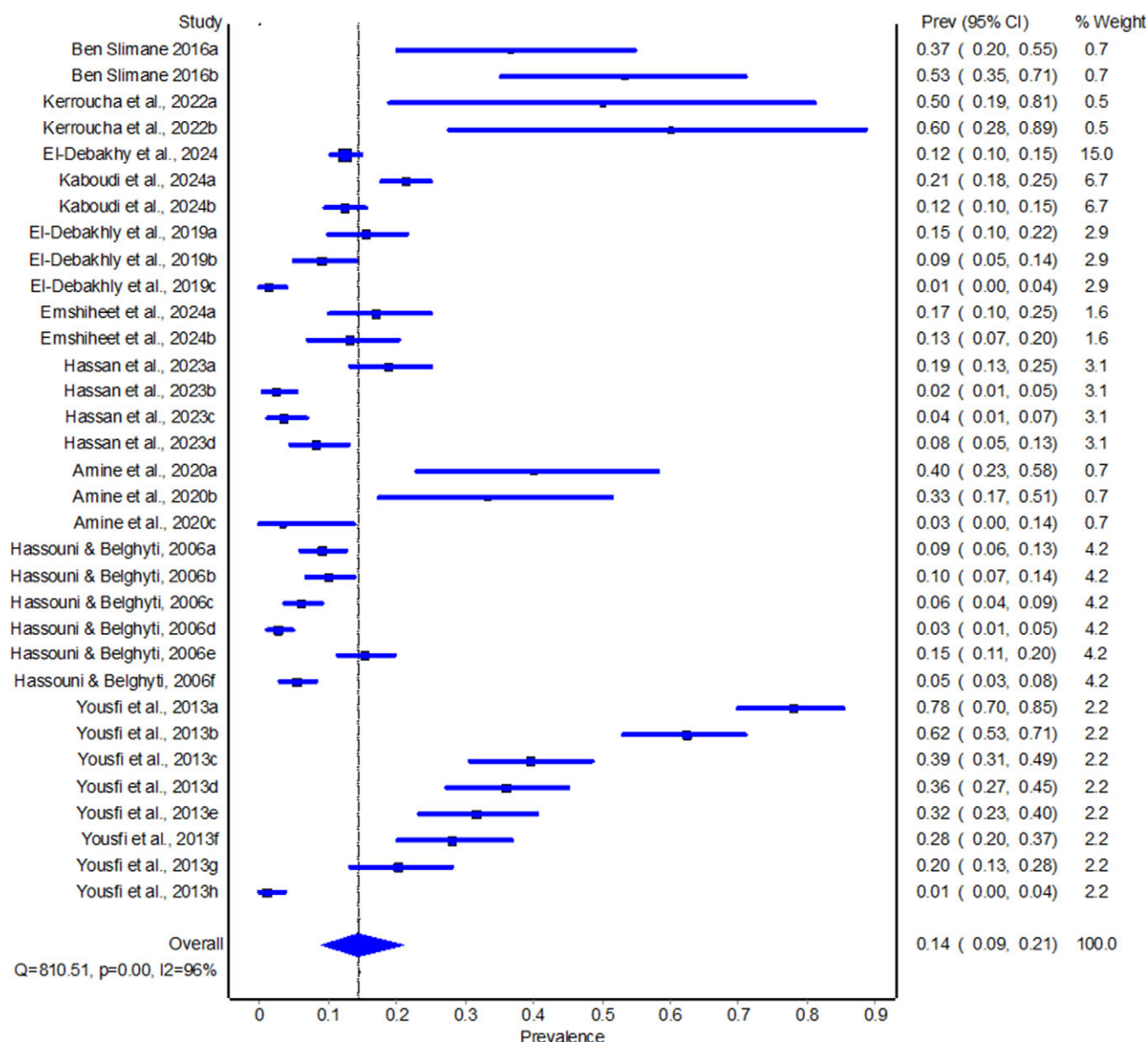


Figure 4. Forest plot for the prevalence of gastrointestinal nematode species in free-range chickens from Northern Africa from 1993 to 2024.

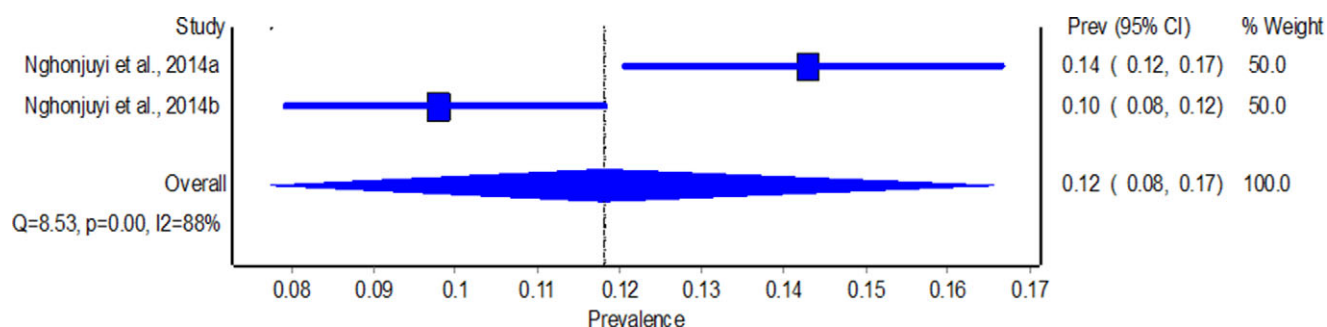


Figure 5. Forest plot for the prevalence of gastrointestinal nematode species in free-range chickens from Central Africa from 1993 to 2024.

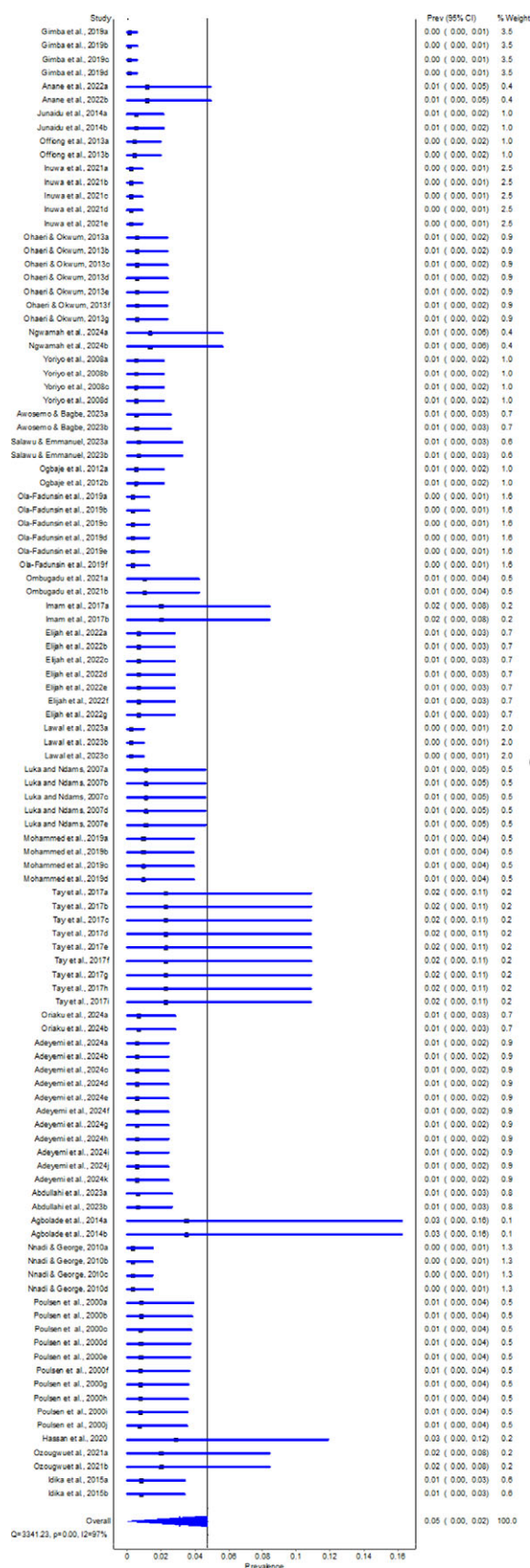


Figure 6. Forest plot for the prevalence of gastrointestinal nematode species in free-range chickens from Western Africa from 1993 to 2024.

Discussion

The overall prevalence of the nematode species infection in free-ranging chickens in Africa was 15%. The prevalence could have been influenced by several factors, such as distribution and availability of intermediate hosts and/or environmental contamination with infective parasite eggs or larvae (Opara et al., 2014). Additionally, the GIT nematode prevalence might have been attributed to the differences in the feeding patterns of the birds, the incidence of the infective stages, and the intermediate hosts of the parasites picked up by the birds or found in places where the chickens free ranged.

Tetrameridae was found to be a common nematode family parasitising free-range chickens, particularly species from the genus *Tetrameres*. Agüero et al. (2016) reported the *Tetrameres* spp. to have worldwide distribution, and one of its representative species, *T. americana*, has been reported as a common parasite of free-range chickens in tropical and subtropical areas with high prevalence (Fink et al. 2005). In tropical Africa, *Tetrameres* genus usually results in high prevalence infections in free-ranging chickens (Wamboi et al. 2020), and the present study recorded a pooled prevalence of 54% for the Tetrameridae, which included species such as *T. americana* and *T. fissispina*. According to Magwisha et al. (2002), the observed high prevalence from this family may be attributed to the parasite's transmission dynamics, which involves a variety of arthropods that may be season-dependent, aiding in its proliferation. *Tetrameres americana* was documented in 12 countries from eastern Africa, western Africa, and southern Africa (Chilinda et al. 2020; Fink et al. 2005; Jinga et al. 2012; Magwisha et al. 2002; Permin et al. 1997; Permin et al. 2002), whereas *T. fissispina* was documented in three countries from eastern Africa and western Africa (Magwisha et al. 2002; Olwande et al. 2016; Poulsen et al. 2000). These two species primarily infect the proventriculus and oesophagus of chickens (Mungube et al. 2008; Permin et al. 1997), which may potentially cause severe pathological lesions within these organs.

In contrast, Syngamidae and Spiruridae had the least recorded prevalence, with most reported studies for Syngamidae recording *S. trachea* as the main species affecting free-range chickens, and all three studies for Spiruridae reported *Ha. gallinarum*. Despite the low prevalence, *S. trachea* showed a wider distribution, recorded in 19 countries across the eastern, western, and southern regions, whereas *Ha. gallinarum* was recorded in three countries from the western region of Africa (Tay et al. 2017). *Syngamus trachea* infects birds through multiple transmission mechanisms, such as directly ingesting third-stage larvae (L₃) from embryonated eggs or free L₃ in contaminated environments (soil, feed, water) or indirectly through ingestion of paratenic hosts such as earthworms and other invertebrates, including snails, slugs, beetles, and flies (Gethings et al. 2016). According to Ngongeh et al. (2012), the high pre-parasitic stage of the parasite can be maintained within the environment due to bionomic factors such as high temperatures and high humidity. However, the low infection percentage revealed seems to be due to less favourable conditions associated with free-ranging poultry management systems, which is a possibility, according to Thapa et al. (2015), who further highlighted the complexities of on-farm transmission dynamics in relation to helminth infections.

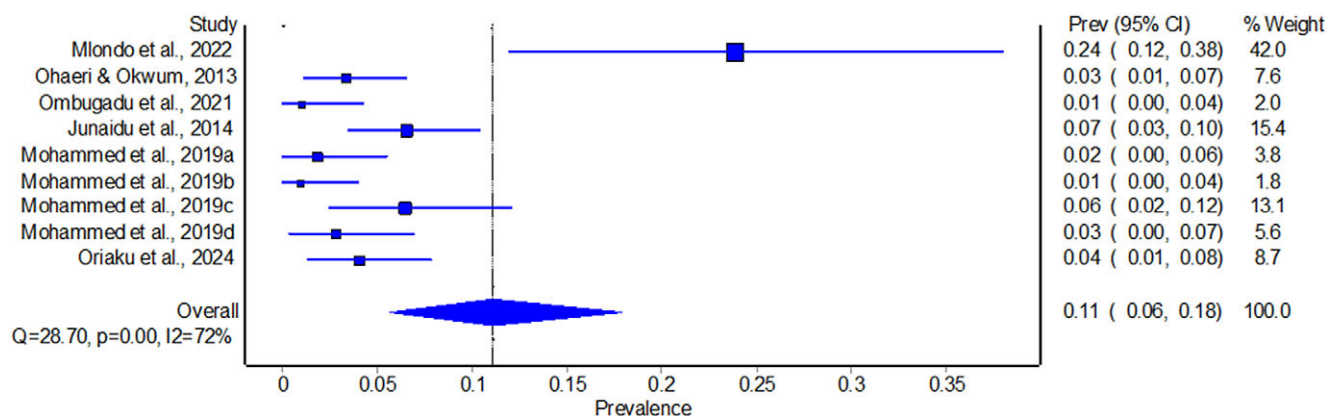
The most reported nematode species were *A. galli* and *H. gallinarum*, which occurred in all reported African regions. These species have been reported globally with a high prevalence (García

Table 2. Prevalence of nematode families affecting free-ranging chickens from 1993 to 2024

Nematode Family	No. of studies	Sample size	No. positive	Prevalence (95% CI)	I^2 (%)	Q-value	P-value
Acuariidae	19	5056	461	8 (4–12%)	95	446.35	<0.01
Ascaridiidae	76	16,332	4428	26 (21–31%)	97	2495.19	<0.01
Capillaridae	20	11,292	1092	7 (4–12%)	98	1811.40	<0.01
Gongylonematidae	18	2828	685	19 (7–35%)	98	808.1	<0.01
Heterakidae	70	17,440	3990	20 (15–26%)	98	4822.94	<0.01
Spiruridae	3	302	3	1 (0–3%)	0	1.53	>0.01
Strongylidae	13	3496	194	5 (2–8%)	91	139.45	<0.01
Subuluridae	30	6689	1158	14 (6–23%)	98	2005.95	<0.01
Syngamidae	19	5604	169	2 (1–4%)	90	175.57	<0.01
Tetrameridae	14	2938	1248	46 (28–64%)	98	698.16	<0.01
Trichostrongylidae	10	3077	195	4 (1–10%)	97	297.41	<0.01

Table 3. Pooled prevalence of gastrointestinal nematode infection in free-ranging chickens in Africa based on different risk factors

Variables	Subgroup	No. of studies	Sample size	No. positive	Prevalence estimate (95% CI)	Heterogeneity		
						P-value	Q-value	I^2 (%)
Sex	Female	7	1105	531	46 (27–66)	<0.01	180.17	97
	Male	7	1017	481	45 (30–60)	<0.01	111.29	95
Age	Young	3	647	292	45 (21–71)	<0.01	56.49	96
	Adult	3	551	238	42 (14–72)	<0.01	87.18	98
Diagnostic type	Necropsy	48	51,328	10,423	17 (14–20)	<0.01	15,556.55	98
	Coproscopy	27	21,633	2918	10 (7–14)	<0.01	3657.51	98
	Necropsy+molecular	4	1366	236	15 (3–33)	<0.01	74.07	92
Study period	1993–2002	8	20,698	4534	17 (11–24)	<0.01	7490.19	99
	2003–2013	18	23,232	3941	14 (10–19)	<0.01	5658.83	98
	2014–2024	50	30,859	5150	14 (10–17)	<0.01	6440.23	97

**Figure 7.** Forest plot for the prevalence of gastrointestinal nematode species in free-range chickens according to mixed infections.

Cuadrado et al. 2021; Kaufmann et al. 2011; Thapa et al. 2015; Wuthijaree et al. 2019). Similarity in rate of infection could be accounted for by their co-occurrence and co-infection as both parasites have similar life cycles and have the same environmental

conditions requirements for transmission (Das et al. 2017). *Ascaridia galli* and *H. gallinarum* are among poultry's most common and important helminth infections, with the former having the capability of causing diarrhoea, poor growth, egg drop in laying chickens,

and in severe infections, blood loss due to intestinal mucosa damage, secondary bacterial infections, and intestinal obstruction in cases of heavy infections (Ashenafi and Eshetu 2004). Comparatively, *H. gallinarum* is non-pathogenic; however, it plays a crucial role as a potential vector of *Histomonas meleagridis*, a highly pathogenic etiologic agent of 'blackhead disease' (histomoniasis) in many avian species, including chickens (Pinckney et al. 2008). Ashenafi and Eshetu (2004) noted a colossal infection by *H. gallinarum* in free-range backyard chickens which led to severe debility, morbidity, and mortality in extreme cases.

Southern Africa recorded the highest pooled prevalence of gastrointestinal nematode species of free-ranging chickens, and according to Marumbwa et al. (2019), the subtropical and temperate zones of this region, along with its moderate to high rainfall and optimal temperature range (20–30°C) create ideal conditions which may accelerate the development and survival of nematode eggs and larvae on soil and vegetation (Wuthijaree et al. 2019). Furthermore, Marumbwa et al. (2019) also highlighted that southern Africa faces climate variability where the El Niño-induced droughts, followed by floods, can stress chickens and weaken their immune systems, leading to increased parasite proliferation with the return of the rains. Despite recording the highest pooled prevalence, southern Africa had a lower GIT nematode species diversity ($n = 13$) compared to the western Africa region ($n = 23$). However, individual species prevalence ranges differed distinctly, with southern Africa reaching as high as 100%, while western Africa ranged from 6% to 16%. Several authors noted that these variations in prevalence may be linked to seasonality and region, which also influence the occurrence and intensities of some species (Ashenafi and Eshetu 2004; Jinga et al. 2012; Magwisha et al. 2002). Wuthijaree et al. (2019) also reported that adequate moisture and temperature in the environment are indeed the most determinant factors for the development of the infective stage of the helminth parasite, and that may influence the epidemiology of parasite infection.

Despite most studies and the highest species diversity recorded between 2014 and 2024, the highest pooled prevalence of nematode species in free-range chickens was demonstrated between 1993 and 2002. A lack of proper vector-controlling methods and the inadequate supply of vaccine administration to free-range chicken production could have played a role in attaining high infections during that particular period (Malatji et al. 2016). Conversely, frequently communicated information from the campaigns on the sustainable development goals promoted globally, regionally, and nationally could have contributed to the lower prevalence in the recent decade (2014–2024). This increase is driven by the high demand for free-range chickens as reported in many regions in Africa (Malatji et al. 2016; Mtileni et al. 2009; Muchadeyi et al. 2004) and awareness of the economic impact of nematode parasites on the health of free-range chicken production (Berhe et al. 2019; Mukaratirwa et al. 2001; Mwale and Masika 2011).

The pooled prevalence of gastrointestinal nematodes in free-range chickens based on sex was slightly higher in females (46%) compared to males (45%). Physiological, morphological, and behavioural differences between females and males could influence the susceptibility to parasite infections (Kaboudi et al. 2024). Furthermore, the higher infection in females could be attributed to the fact that male chickens under any condition of management tend to court the females by allowing them to feed first before the males, and in so doing, they are more likely to easily acquire infective pathogens than the males (Opara et al. 2014). In addition, the females are known to be more voracious in their feeding habits, especially during egg production, compared to males,

which remain largely selective (Mohammed et al. 2019). However, according to Kaboudi et al. (2024), the prevalence of helminth infections did not differ between female and male birds, indicating that helminth species have no natural affinity for either sex of host chicken.

Age is also considered a risk factor associated with the occurrence of GIT helminth infections (Kaboudi et al. 2024). The pooled prevalence of GIT nematodes was higher in young free-range chickens compared to adults. Younger animals are highly susceptible to helminth infections compared to adults, possibly due to their immature immune system and poor acclimatisation to their immediate environment (Ola-Fadunsin et al. 2019).

The quality effects model revealed a relatively average heterogeneity with mixed infections, and the pooled prevalence according to mixed infections of gastrointestinal nematodes was ascertained. The endemicity of mixed infections could be related to environmental factors and poor hygienic conditions in the backyard system, which are favourable for developing parasitic infections (Kaboudi et al. 2024). Gastrointestinal tract helminths are either commonly over-dispersed or aggregated within the host population. Aggregation can be attributed to several factors, including heterogeneity in the host behaviour influencing the uptake of infective stages and spatial heterogeneity in the distribution of infective stages (Hussen et al. 2012). Mixed infections in rural free-ranging chickens have been reported in several studies (Mohammed et al. 2019; Ohaeri and Okwum 2013; Yoriyo et al. 2008). According to Smyth (1976), the establishment of mixed infection involving one or multiple species might be attributed to the food selected and consumed by the chicken at a particular time, which may be contaminated and ultimately leads to infection.

Substantial heterogeneity was observed between prevalence studies across the continent. The potential source of variation, as indicated by the meta-regression results, was the differences in diagnostic/detection methods employed when carrying out the studies, which showed a significant difference in the pooled prevalence of nematode infections. The highest prevalence was attained through necropsy compared to coproscopy. Our results concur with those attained by Shifaw et al. (2021), where they found that the widely used diagnostic method was necropsy examination. Necropsy is known for its accuracy and reliability for detection and identification of GIT helminths in chickens (Macklin 2013); however, the method may not be the most economically viable method for routine diagnosis, as it involves sacrificing individual chickens. Varying prevalence rates noted in the cited studies could have been a result of them being conducted in different seasons, use of different ages of the chickens, environmental sources with varying availability of intermediate hosts, and study chickens with different individual host resistance (Sahu et al. 2016).

Strengths and limitations

The current study is the first systematic review to document the pooled prevalence of GIT nematode species in free-ranging chickens from various sub-regions of Africa covering a broad research period. In addition, the strengths of the systematic review and meta-analysis were adherence to the criteria and the principles of the PRISMA guidelines, the provision of estimates based on a quality effects model, and the analysis conducted per subgroup for heterogeneity. Despite using a standardised analysis process, it was difficult to achieve a consistent meta-analysis due to the different attributes that were included for the accountability towards the heterogeneity. Therefore, there was a limitation of

publication bias. A subsequent number of studies in this review primarily identified most of the nematode species based on morphological approaches. The inability to identify nematodes to the species level led to the exclusion of several articles in the meta-analysis that could have aided in the estimation of the prevalence of the GIT nematodes. The low number of published articles that were eligible for the review was not evenly distributed across the subregions of Africa. Meta-analysis could not be conducted on some of the nematode families due to the limited number of studies carried out. Thus, in this review, the prevalence data may not fully represent the prevalence of GIT nematode species affecting free-ranging chickens across Africa.

Conclusions

This review provides insights into the occurrence and prevalence of GIT nematode infections in free-ranging chickens across African sub-regions. The study highlighted the lessening of parasitic nematode species burden in free-range chickens; however, there is a higher GIT nematode species diversity and a wider distribution of the most prevalent species across Africa. Such evidence indicates a serious long-term and regional threat to sustainable free-range chicken production due to increased pathogenic potential and subsequent complications in disease control, ultimately resulting in significant reductions in flock productivity. The study also recommended future studies that involve the integration of both morphological and molecular techniques to increase the accuracy of parasite identification to the species level. Furthermore, this will aid in determining species-specific distribution and regional species biodiversity, which will assist in investigating the transmission dynamics of these parasites and the development of sustainable control strategies.

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