



A systematic review and meta-analysis of the prevalence of parasitic infections in equids in Ethiopia

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Abstract

We performed this review to determine the weighted prevalence of equids parasitic infections in Ethiopia. Article searches on parasites of equids were conducted using PubMed, PubMed Central, Google Scholar, Science Direct, Web of Sciences, Scopus, AJOLs and Research Gate. A random effects model was used to estimate the weighted prevalence and to study heterogeneity. The primary searches generated, 3082 potential studies, of which 66 reports met the inclusion criteria and were included in the meta-analysis. There were 32 reports involving two or more equids species, eighteen on donkeys, and sixteen on horses. Moreover, fifty of the reports mentioned helminth infections in equids, thirteen on protozoans, and three on ectoparasites. The estimated weighted prevalence of parasitic infections in equids was 58.3% (95% CI 50.8–65.4%, $I^2 = 99%$). Helminths were the most prevalent parasites in equids, accounting for 77.1% (95% CI 71.4%, 82%, $I^2 = 98.5%$), followed by ectoparasites at 35.4% (95% CI 33.4–37.52%, $I^2 = 88.2%$) and haemoparasites (protozoans) at 10.84% (95% CI 6.6%, 17.3%, $I^2 = 98.1%$). Furthermore, with a prevalence of 82.3% (95% CI 75.9–87.3%, $I^2 = 97.4%$), donkeys were the most affected equids with helminth parasites. From the reports, we found forty-three species of helminth parasites affecting equids, including thirty-four nematode species (*Strongylus*, *Cyathostomum*, *Coronocyclus*, *Cylicocyclus*, *Cylicostephanus*, *Trichostrongylus*, *Oesophagodontus*, *Strongyloides*, *Triodontophorus*, *Gyalocephalus*, *Poteriostomum*, *Dictyocaulus*, *Oxyuris*, *Habronema*, *Draschia*, *Parascaris*, *Setaria*, and *Probstmayria* species), three trematodes (two *Fasciola* and one *Gastrodiscus* species), three cestodes (two *Anoplocephala* and one *Anoplocephaloides* species) and three botfly larvae (one *Rhinoestrus* and two *Gasterophilus* species). *Trypanosoma* species (*T. congolense*, *T. vivax*, *T. brucei*, *T. equiperdum*, and *T. evansi*), piroplasms (*Theileria equi* and *Babesia caballi*), and *Eimeria* species have also been reported to affect equids. Ticks (*Amblyomma variegatum*, *A. gemma*, *Rhipicephalus decoloratus*, *R. evertisi evertisi*, *R. pulchellus*, *R. muhsame*, *R. sanguineus*, *Hyalomma rufipes*, and *Hy. truncatum*) and lice (*Bovicola equi* and *Haematopinus asini*) were the ectoparasites recorded to affect equids. The risk of publication bias across studies was likely to be high due to differences in publication year and diagnostic techniques. In conclusion, parasitic infections of equids are common in Ethiopia and are caused by a variety of parasite species, putting the performance and well-being of these packing animals at risk. Therefore, more research is needed to identify infection risk factors and raise awareness of the consequences of parasitism in order to provide strategies to mitigate the problems in equids.

Keywords Ethiopia · Equids · Meta-analysis · Parasites · Prevalence · Systematic review

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Introduction

Ethiopia has 10.80 million donkeys, 2.15 million horses, and 0.33 million mules, accounting for roughly half of Africa's equids population (CSA 2021). Equids are important in Ethiopia's agricultural economy and are used for a variety of tasks in both rural and impoverished urban communities. They play an important role in transportation (riding, packing, and cart pulling), farming (tillage and threshing), weddings and tourism, water and milling, and so on (Kumsa et al. 2012; Seyoum et al. 2015). Equids have received far less attention in terms of health management than other livestock species, despite their significant contribution to the country's transportation and agricultural economies (Seyoum et al. 2015). This could be due to communities' long-held belief that equids are hard and tolerant, as well as the fact that they do not provide meat or milk (Kumsa et al. 2012). In Ethiopia, the main factors affecting equids health and performance are a lack of feed, working stress, and diseases (of parasitic, bacterial, viral, and nutritional origin) (Sheferaw and Alemu 2013).

Parasitic diseases are major threats to the health, welfare, and performance of equids, particularly in developing countries (Khamesipour et al. 2021). Endoparasites (helminths, protozoans, and arthropod larvae) and ectoparasites (ticks, mites, lice, and flies) are the two types of equids parasites (Khamesipour et al. 2021). Helminths are the most serious and well-known parasites in equids (Getachew et al. 2010; Valdéz-Cruz et al. 2013; Khamesipour et al. 2021). *Trichostrongylus* spp., *Strongylus* spp., *Cyathostomins*, *Trichuris* spp., *Oxyuris equi*, *Parascaris equorum*, *Probstmayria* spp., *Paramphistomum* spp., *Fasciola* spp., *Dicrocoelium* spp., *Anoplocephala* spp., *Anoplocephaloides* spp., *Dictyocaulus arnfieldi*, *Gastrodiscus* spp., *Habronema* spp., *Draschia* spp., *Gasterophilus* spp., *Strongyloides* spp. and *Triodontophorus* spp. are the common helminth parasites affecting equids (Getachew et al. 2010; Sheferaw and Alemu 2015; Khamesipour et al. 2021). Helminth infection rates in equids from various parts of the world have been estimated to range from 11.2 to 100% (Fikru et al. 2005; Valdéz-Cruz et al. 2013; Getachew et al. 2010; Sheferaw and Alemu 2015). According to reports, helminths can infect over 90% of equids in a given area (Fikru et al. 2005; Getachew et al. 2010). Helminth parasite studies in equids have revealed a wide range of helminth species (Hosseini et al. 2009; Getachew et al. 2010). Almost all equids have helminth parasites, which can impair the animal's performance if left untreated. Helminth parasites primarily affect equids' digestive systems, but the respiratory system and other organs may also be affected (Khamesipour et al. 2021). Ticks and lice are the most common ectoparasites found in equids (Kumsa et al.

2012; Tafese et al. 2014). Protozoa that commonly infect equids include *Eimeria* species, *Theileria equi*, *Babesia caballi*, and *Trypanosoma* species (Hagos et al. 2010a, b; Khamesipour et al. 2021).

In many agro-ecological zones, parasitic infestations pose serious threats to equids populations (Valdéz-Cruz et al. 2013). They affect animal health and welfare, limiting their working performance (Fesseha et al. 2022). Parasitism in equids causes diarrhoea, anaemia, fever, colic, reduced feed intake, emaciation, poor growth rate, poor body condition and traction power, loss of electrolytes and plasma proteins, protein metabolism alterations, increased susceptibility to other infectious diseases, and death (Valdéz-Cruz et al. 2013; Khamesipour et al. 2021). All of these clinical effects result in significant economic losses for farmers. Understanding the status of parasitic infections and the factors that influence epidemiology at the national level is therefore essential and a basic step in improving the health and welfare of equids and developing, implementing, and monitoring an efficient and effective parasitic control strategy.

Several factors have been identified as having an impact on the host-parasite pathogen, epidemiology, biology, and life cycle of equids parasites. These include host factors (age, gender, species, body condition score, and immune status), parasite factors (life cycle, mode of transmission, virulence, and parasite genotype), environmental factors (climate conditions, and geographic factors), and anthropogenic factors (socioeconomic status, community awareness/health care education level, and management practises) (Nielsen et al. 2007). As a result, parasitic infection control measures must rely on strong evidence of the risk factors that contribute to host transmission dynamics. Several studies on equids parasite infections in Ethiopia have been conducted, with prevalence ranging from 1.06 to 100% (Fikru et al. 2005; Getachew et al. 2010; Hagos et al. 2010a, b; Mekibib et al. 2010; Mkuria et al. 2010; Gizachew et al. 2013; Kumsa et al. 2012; Tafese et al. 2014; Getachew et al. 2014; Berhanu et al. 2014; Seyoum et al. 2015; Sheferaw and Alemu 2015; Fesseha et al. 2022). According to these works, equids parasites are the most commonly encountered concerns of working equids. Despite the fact that the prevalence of parasitic infections in equids varies in Ethiopia, the reports are fragmented and not systematically organised to show the national level and to be used as reference data by policymakers and veterinarians to plan strategic control and preventive measures. Furthermore, to the best of our knowledge, no published report on meta-analysis of prevalence estimates and associated risk factors exists. As a result, there is a knowledge gap regarding the trend and prevalence of parasitic infections in equids, as well as the associated risk factors. Detail information about the prevalence and risk factors of equids parasites across the country, on the other hand, is critical for developing strategic control measures and

monitoring the economic impacts in developing countries like Ethiopia. Thus, this systematic review and meta-analysis of existing reports was conducted to provide information on the prevalence and species composition of parasites affecting equids in Ethiopia in order to align control policies.

Methodology

Between September 1, 2022 and November 30, 2022, a literature search was conducted to identify articles reporting parasitic infections of equids in Ethiopia. The current study follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines (Moher et al. 2015). To ensure that all relevant information was included in the analysis, the PRISMA checklist was used.

Literature search

A literature search was carried out to identify articles published between the year of inception and November 30, 2022. The search for papers was carried out by using electronic databases and search engines. We planned to collect all English-language papers on the prevalence of helminths, haemoparasites (protozoans), and ectoparasites in equids throughout Ethiopia. The papers were found in PubMed, PubMed Central, Google Scholar, Science Direct, AJOLs, Web of Sciences, Scopus and Research Gate. There was no time limit set for the search strategy. To identify relevant articles or papers, we used various medical subject heading (MeSH) terms and a variety of relevant keywords such as “Epidemiology”, “Prevalence”, “Endoparasite”, “Ectoparasite”, “Nematode”, “Helminths”, “Gastrointestinal parasite”, “Tick”, “Mite”, “Lice”, “Equids”, “Horse”, “Mule”, “Donkey” and “Ethiopia”. Additionally, studies were identified by checking cross-references in collected articles. We used the “OR” and “AND” Boolean operators to find the aforementioned terms.

Inclusion criteria

Articles reporting parasitic infections in equids were retrieved, regardless of the diagnostic method used to confirm parasitic infections (coprological, serological, morphological, or molecular methods). The inclusion criteria for the studies were developed based on the study's objectives. As a result, the retrieved papers were considered for systematic review and meta-analysis based on the following inclusion criteria: studies that were (1) conducted in Ethiopia and focused on equids ectoparasite, endoparasite, or both; (2) original research articles and theses; (3) published in English between 2000 and 2022; (4) cross-sectional; (5) reported the prevalence or epidemiology and risk factors

of endoparasite and ectoparasite; and (6) their target study population included equids species (greater or equal to 30 animals). Papers that did not meet the above criteria were rejected.

Study selection and data extraction

Two independent reviewers identified articles reporting parasitic infections in equids in Ethiopia based on the title and abstract of the paper. It was carried out in accordance with the predefined inclusion criteria. Before conducting the screening assessment, duplicates were initially removed. As a result, studies were excluded if the titles and abstracts were unrelated to the outcomes of interest or did not meet the eligibility criteria. Following that, the full texts of eligible studies were thoroughly reviewed to ensure their suitability for the analysis. A third reviewer was consulted in the event of a disagreement between the two reviewers. The third reviewer also validated the records. Finally, data was extracted using a standardised data collection form. The following information was collected from each selected study: first author, year of publication, study year, geographic location and region of the study, study design, study population, sample size, sampling method, diagnostic technique, type of parasite identified, host involved, risk factor identified, and event rate, which was then saved in an Excel spreadsheet. Figure 1 depicts the study's search strategies and exclusion criteria in detail.

Quality assessment study

Two independent researchers assessed the quality of the selected studies using a quality assessment checklist (standard strengthening the Reporting of Observational Studies in Epidemiology checklist (STROBE)) (von Elm et al. 2007). This checklist includes 22 items that comprise various sections of the articles, including the title, abstract, introduction, methods, results, and discussion. The checklist included items assessing the studies' objectives, various method components (e.g., study design, sample size, study population, bias, statistical methods), results, limitations, and funding.

Data synthesis and statistical analysis

Data were extracted and stored in an Excel spreadsheet before being exported and analysed in STATA version 17 (Stata Corp., College Station, TX, USA). The meta-analysis was carried out in accordance with the protocol described by DerSimonian and Laird (1986) in order to examine the pooled prevalence of parasitic infections in equids using the eligible searches. In brief, helminths, protozoans, and ectoparasites of horses were studied separately. For each study, the parasitic infection rate and its

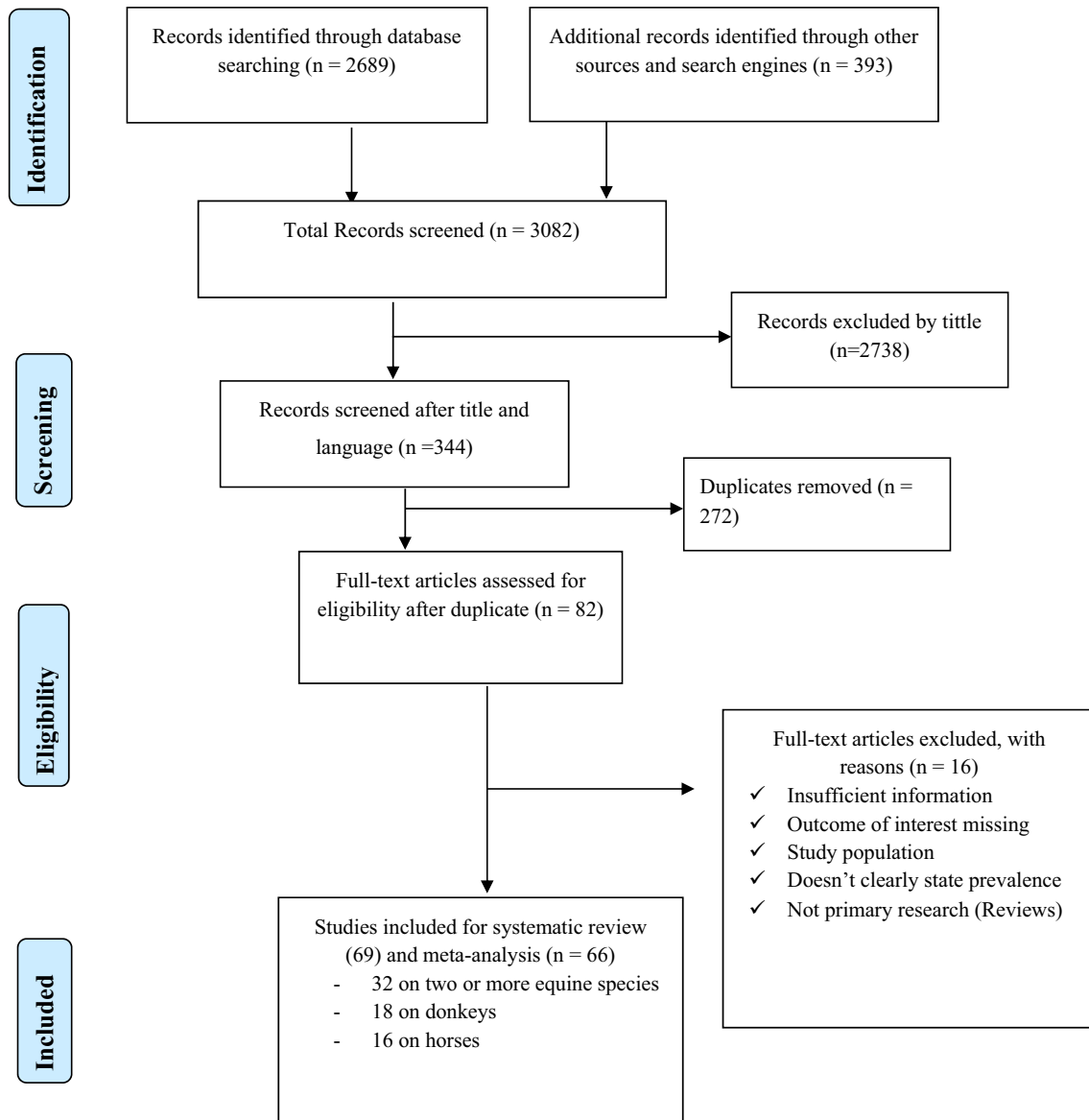


Fig. 1 PRISMA flow chart describing the selection process (Moher et al. 2015)

95% confidence interval (CI) in equids were calculated. Using the formula provided by Barendregt et al. (2013), the study level event rate was transformed to logit event rate. For ease of interpretation, the logit event rates were back transformed to prevalence event rates (prevalence estimates). In pooled prevalence analysis and 95% confidence intervals (95% CIs), the random-effects model with the Der-Simonian-Laird method of selection was used (Moher et al. 2015). To present the differences between studies, meta-analysis results displaying estimates of prevalence, and their corresponding confidence intervals (CIs) of all included studies with the pooled effect size, a Forest plot diagram was used. To determine heterogeneity

and consistency among studies, the inverse variance index (I^2) and Cochran's Q test were calculated, and I^2 values of 25, 50, and 75% were regarded as indicating low, medium, and high heterogeneity, respectively (Higgins and Thompson 2002). To confirm the heterogeneity of study level estimates, a Galbraith plot was also constructed. Small study effects and the presence of publication bias were then visualised using funnel plot diagrams, Egger's and Begg's tests (Borenstein et al. 2009). The studies were also classified geographically (north, east, south, central, west, northeast, northwest, southeast, and southwest), and the total prevalence was assessed in six different regions. Figures and tables were used to display the summarised and descriptive results.

Results

Study characteristics and search results

The authors conducted a systematic review and meta-analysis on published and unpublished (thesis) reports of parasitic infestations of equids in Ethiopia. The period of literature search began in September 2022 and ended in November 2022. We initially identified 3082 reports, 2738 of which were rejected due to title screening indicating irrelevance to the review. The reference manager software (EndNote-TM) and manual confirmation were used to identify duplicates among the remaining 344 papers. Following that, 82 articles were evaluated based on eligibility criteria. Although 69 of these studies were suitable for systematic review, only 66 met the quantitative and meta-analysis requirements (Fig. 1, S1Table). As a result, 47 helminth studies, 16 protozoans (haemoparasites), and 3 ectoparasite studies were considered for meta-analysis. All of these studies were carried out between 2002 and 2021, and they all used a cross-sectional study design with purposive, simple, systematic, and multistage sampling techniques. The identified studies were carried out in various geographical areas of Ethiopia. Seventeen of the studies were conducted in Ethiopia's central, five in the northern, thirteen in the north-western, ten in the southern, four in the south-western, one in the western, two in the eastern, five in the north-eastern, and nine in the south-eastern regions. Furthermore, depending on the parasite type, coprological, morphological, post-mortem, serological, and molecular laboratory techniques were used. Fourteen reports of parasitic infections on the three equid species (donkeys, horses, and mules) were noted; thirteen on both donkeys and horses; four on both donkeys and mules; nineteen on donkeys alone and sixteen on horses alone (S1Table). The included studies in the quantitative and meta-analysis had a total sample size of 28,025 equids (12,299 donkeys, 14,228 horses and 1,498 mules). Sixteen thousand four equids were found to be infected with equids parasites. Helminth, haemoparasite (protozoan), and ectoparasite apparent infection rates were found in 72.5%, 18.3%, and 35.38% of equids, respectively.

Meta-analysis and bias evaluation

For the current quantitative and meta-analysis, 66 studies written in English were used. Fourteen of them were reported the parasitic infections in equids (donkeys, horses and mules) at a weighted (pooled) prevalence of 62% (95% CI 48–74.2%), thirteen on both donkeys and horses 75.6% (95% CI 64.7%, 83.9%), four on both donkeys and mules

72.7% (95% CI 55.9–84.9%), nineteen on donkeys alone 42.7% (95% CI 22.7–65.3%) and sixteen on horses alone 53.5% (95% CI 38.6–67.8%).

The studies retrieved were carried out between 2002 and 2021 in order to estimate the prevalence of parasitic infections in equids in various parts of Ethiopia. The geographic distribution of the studies in Ethiopia shows that seventeen studies were in the central at a pooled prevalence of 52% (95% CI 38–66%), thirteen in the north-western 59.6% (95% CI 38.4–77.7%), ten in the southern 76.1% (95% CI 58.8–87.6%), nine in the south-eastern 52% (95% CI 30.4–72.7%), five in the northern 25.9% (95% CI 13.1–44.7%), five in the north-eastern 69% (95% CI 58.3–77.5%), four in the south-western 42.8% (95% CI 16.1–74.5%), two in the eastern 87.1% (95% CI 59–97%) and one 92.8% (95% CI 89.7–95%) in the western parts of Ethiopia (S1Table). Figure 2 depicts the geographic distribution of studies by location. Similarly, the distribution of published studies retrieved from 2002 to 2021 depicted the temporal pattern of the study years. The majority of the retrieved studies (57.6%) were conducted after the year 2013 (Fig. 3). We confirmed a significant scarcity of studies between 2002 and 2010 (18.2%, or 12/66 studies). The investigation of a time series model to predict the trend of the number of studies over time revealed a slower increasing trend beginning in 2016 with a trend line of equation $Y = 0.0206x + 3.95$. The intercept value for the stated equation indicated a few ongoing studies (0.0206), indicating a significant variation in the number of studies over time (Fig. 3).

Overall, the apparent prevalence of parasitic infection in equids ranged from 1.06 to 100% (S1Table). The overall weighted prevalence of parasitic infections in equids was estimated to be 58.3% (95% CI 50.9–65.4%). There was significant heterogeneity in reports of parasitic infections in equids ($I^2 = 99\%$, Q -test = 6345.13, $df = 65$, $p < 0.0001$). Figure 4 depicts the forest-plot analysis for the study of parasitic infections in equids. The Galbraith plot analysis of studies on parasitic infections in equids (Fig. 5) revealed that almost all the included studies are located outside the 95% confidence limit, demonstrating the heterogeneity of the studies. Furthermore, for small study effects, publication bias was assessed using funnel plot observation and risk bias coefficient tests (Egger's and Begg's tests) for studies published on parasitic infections in equids in Ethiopia. The funnel plot observation results show a symmetrical observation (Fig. 6), indicating that smaller studies are not missed to be reported to the scientific community. Similarly, as shown in Fig. 7, the results of Egger's test plot revealed no significant publication bias (but not Begg's test plot) in estimating the prevalence of parasitic infections in equids (Egger's test: $b = 0.78$, 95% CI -5.02, 6.58, $p = 0.79$ and Begg's test: $p = 0.038$).

Donkeys 65% (95% CI 54.4–74.4%, $I^2 = 98.5\%$) and mules 64.4% (95% CI 53–74.4%, $I^2 = 92.9\%$) had a higher weighted

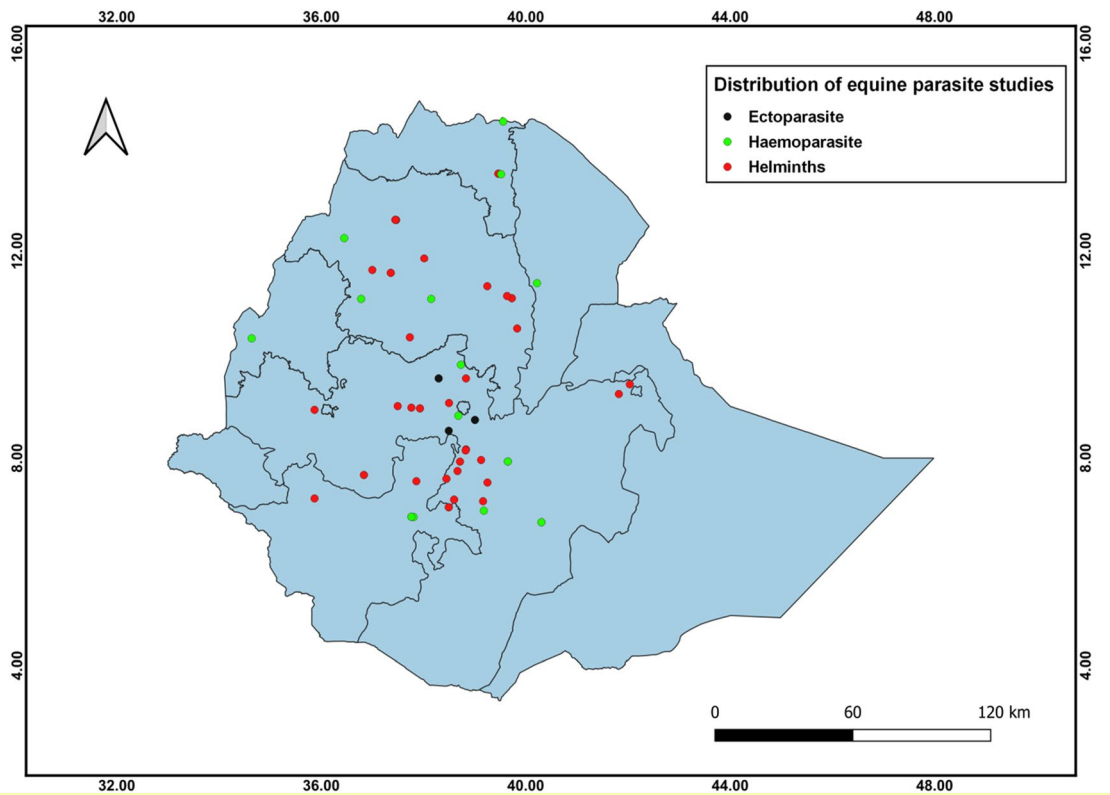
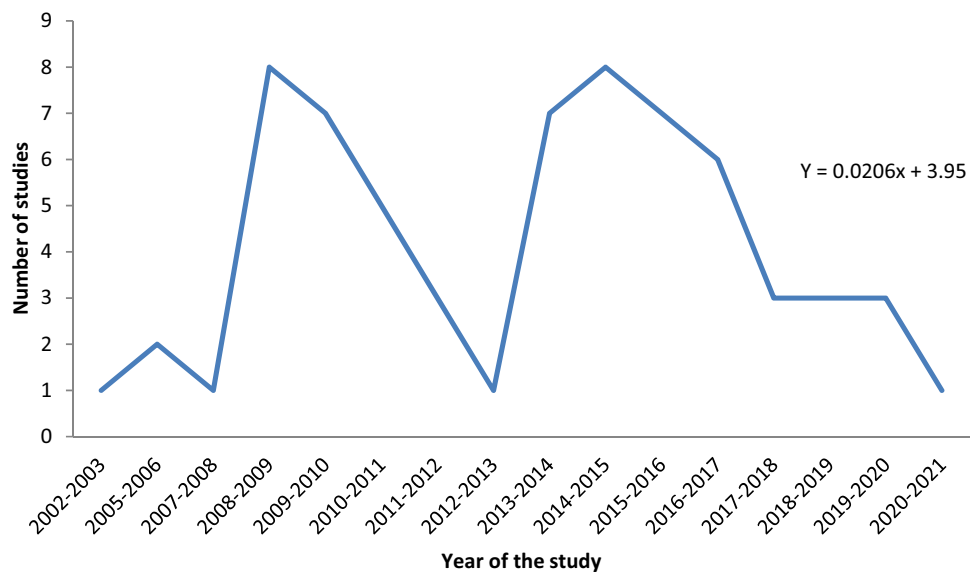


Fig. 2 Distribution of studies performed on equids parasites in Ethiopia

Fig. 3 Trendline and equation depicting the growing trend of published articles over years



prevalence of parasitic infections than horses 58.8% (95% CI 50.2–66.8%, $I^2 = 98.6\%$). Helminths were the most widely prevalent parasites of equids and the weighted prevalence was 77.1% (95% CI 71.4%, 82%, $I^2 = 98.5\%$), followed by ectoparasites 35.4% (95% CI 33.4%, 37.5%, $I^2 = 88.2\%$) and haemoparasites (protozoans) 10.84% (95% CI 6.6%, 17.3%,

$I^2 = 98.1\%$). Donkeys had the highest prevalence of helminth parasites at 82.3% (95% CI 75.9%, 87.3%, $I^2 = 97.4\%$), followed by horses at 66.2% (95% CI 57.9%, 73.7%, $I^2 = 97.9\%$) and mules at 64.4% (95% CI 53%, 74.4%, $I^2 = 92.9\%$). Horses, on the other hand, were the most affected equids with haemoparasite (protozoa), with a prevalence of 24.5%

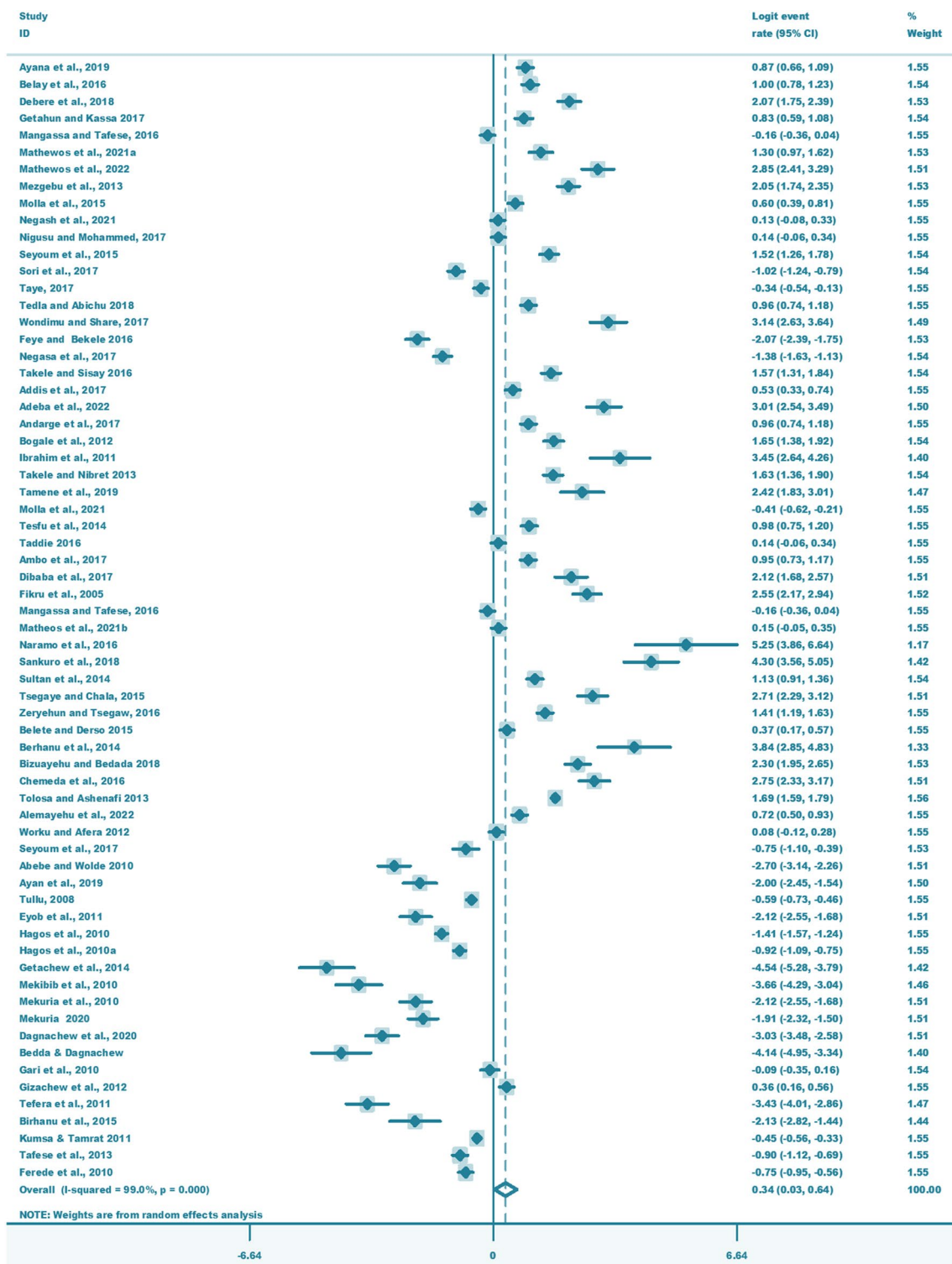


Fig. 4 Forest plot of the logit event rate (Ip) of parasitic infections in equids in Ethiopia

(95% CI 17%, 34%) compared to donkeys 6.1% (95% CI 1.92%, 17.64%).

The prevalence of helminth infection was highest in the southern 86.6% (95% CI 78.02%, 92.2%) and eastern

87.1% (95% CI 59%, 97%) regions of Ethiopia, followed by the north-western 81.1% (95% CI 69.4%, 89%) and south-eastern 80.1% (95% CI 62.1–90.8%). The prevalence

Fig. 5 Galbraith plot for the prevalence of parasitic infections in equids in Ethiopia

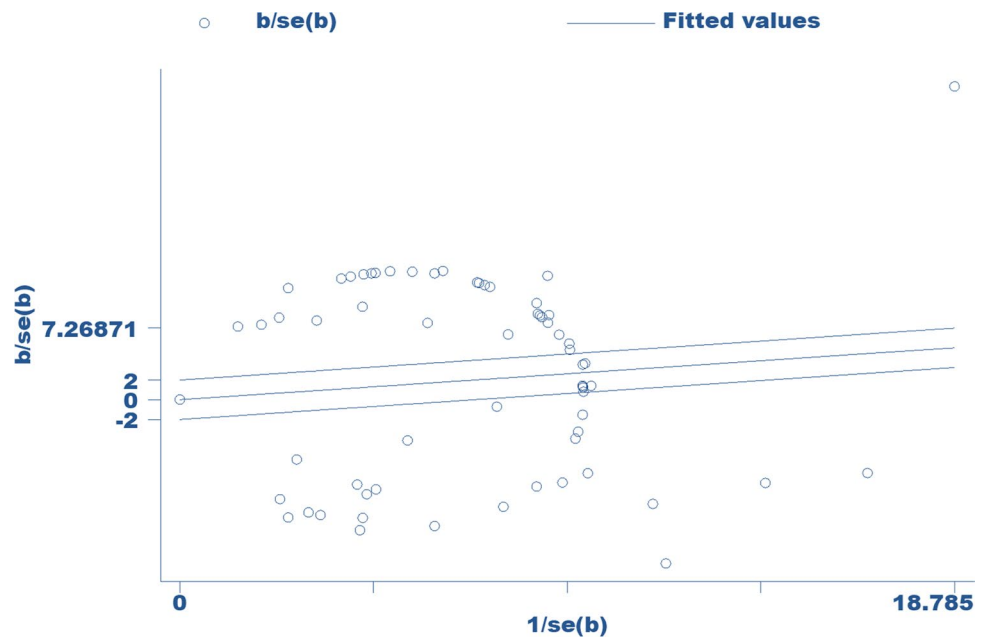
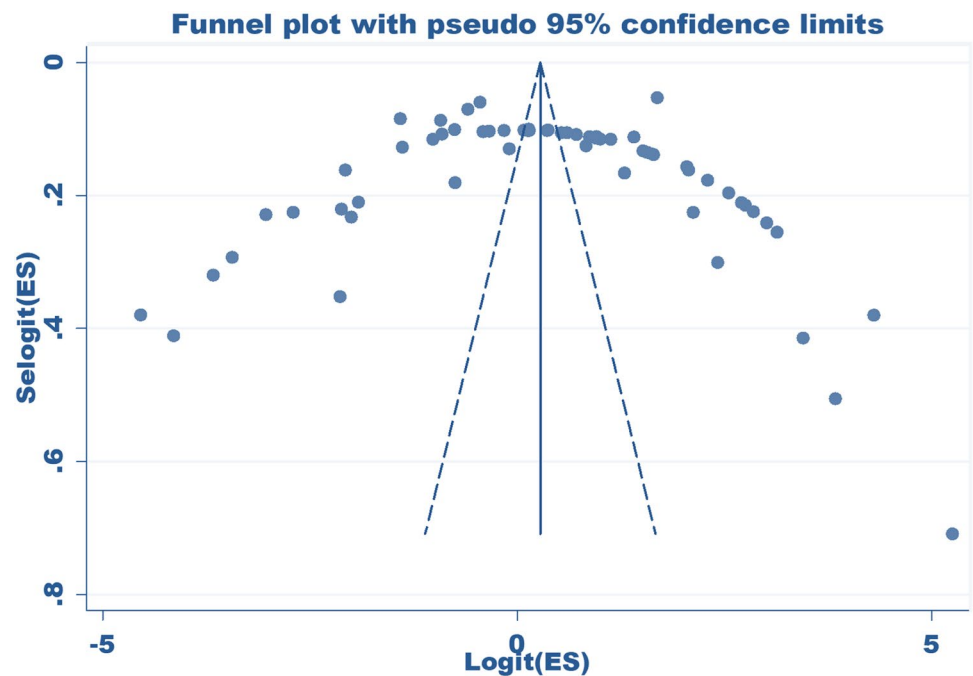


Fig. 6 Funnel plot with 95% confidence limits of the prevalence of parasitic infections in equids in Ethiopia



of protozoa infection, on the other hand, was higher in the country's south-eastern (27.5%) region (Fig. 8).

We found forty-three species of helminth parasites affecting equids from the reports, including thirty-four nematode species (*Strongylus*, *Cyathostomum*, *Coronocylus*, *Cylicocylus*, *Cylicostephanus*, *Trichostrongylus*, *Oesophagodontus*, *Strongyloides*, *Triodontophorus*, *Gyalocephalus*, *Poteriostomum*, *Dictyocaulus*, *Oxyuris*, *Habronema*, *Dra-schia*, *Parascaris*, *Setaria*, and *Probstmayria* species), three trematodes (two *Fasciola* and one *Gastrodiscus* species),

three cestodes (two *Anoplocephala* and one *Anoplocephaloides* species) and three botfly larvae (one *Rhinoestrus* and two *Gasterophilus* species) (S2Table). Equids have also been reported to be infected with *Trypanosoma* species (*T. congolense*, *T. vivax*, *T. brucei*, *T. equiperdum*, and *T. evansi*), piroplasmids (*Theileria equi* and *Babesia cabali*), and *Eimeria* species (S3Table). Ticks (*Amblyomma variegatum*, *A. gemma*, *Rhipicephalus decoloratus*, *R. evertisi evertisi*, *R. pulchellus*, *R. muhsame*, *R. sanguineus*, *Hyalomma rufipes*, and *Hy. truncatum*) and lice (*Bovicola equi*

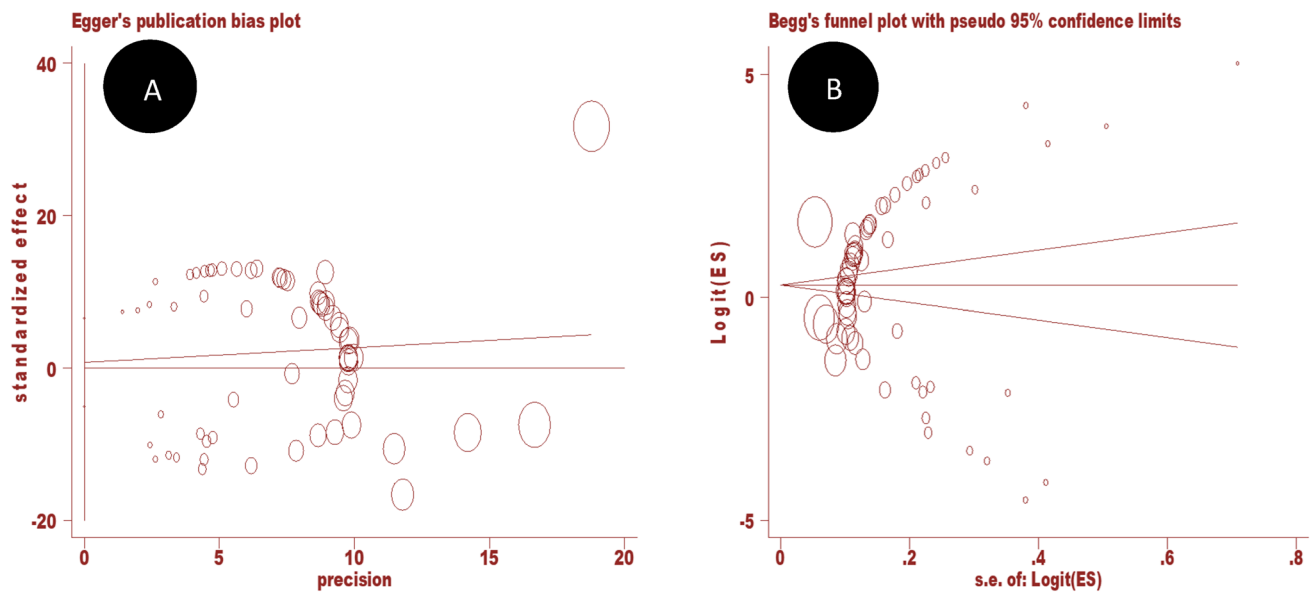
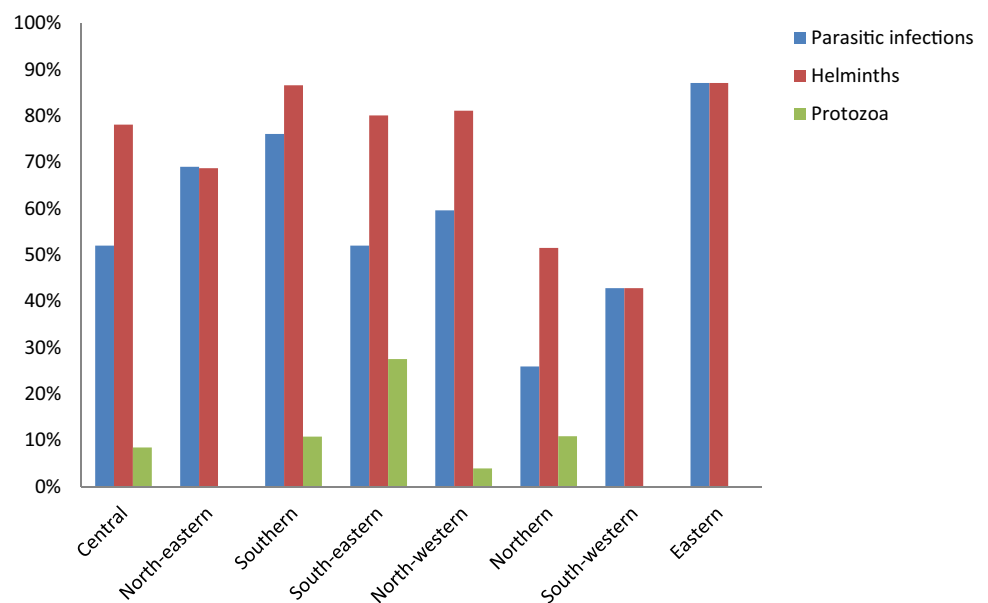


Fig. 7 Egger's publication bias plot (A) and Begg's funnel plot (B) reports on equids parasites

Fig. 8 Pooled prevalence of parasitic infections of equids by geographic locations



and *Haematopinus asini*) were the observed ectoparasites in the equids population (S3Table).

Discussion

Ethiopia has diverse agroclimatic environments that support the survival and growth of various parasites affecting domestic animals, such as helminths and ectoparasites. Equids are frequently overlooked in domestic animal health management because they provide neither meat nor milk (Seyoum

et al. 2015). This could also be due to the fact that equids are thought to be hardy and tolerant (Kumsa et al. 2012). Equids, on the other hand, can have a variety of health issues that limit their ability to participate in transportation and agricultural activities. The most serious of these are endo- and ecto- parasites (Getachew et al. 2010; Kumsa et al. 2012). Equids are also susceptible to parasites with varying life cycles, pathogenicity and epidemiology.

In light of the foregoing, it is critical to synthesise information from previous studies in order to depict the status of parasitic infection in equids. Estimating the national

and regional pooled prevalence of parasite infection in equids could help Ethiopia develop appropriate control and prevention strategies. However, there is a scarcity of comprehensive, systematic data on the prevalence and species composition of equids parasites that contribute to parasite infection in equids. To the best of the authors' knowledge, this is the first systematic review and meta-analysis of equids parasite infections in Ethiopia. The current study collected weighted prevalence estimates, as well as the spatial and temporal distribution of parasitic infections in equids. The study included 66 original studies on the prevalence of parasite infections in equids. Parasitological analysis was performed on faeces, blood/serum, and macro-parasite samples. Coprological, serological, molecular, and morphological (parasitological) analyses were all performed to identify parasites. The central region of the country received the most reports (25.8%), followed by the north-western (20%) and southern (15.2%) regions.

This study found a high prevalence of parasitic infections in equids in Ethiopia. It also revealed polyparasitism with high infection intensity (Getachew et al. 2010; Seyoum et al. 2015; Tolossa and Ashenafi 2013; Sheferaw and Alemu 2015; Ayele et al. 2006; Berhanu et al. 2014; Abebe and Wolde 2010; Mkuria et al. 2010; Dagnachew et al. 2020; Fesseha et al. 2022). Helminths were the most diverse and prevalent parasites infecting equids in Ethiopia, with a prevalence ranging from 97.9 to 100% (Sheferaw and Alemu 2015; Naramo et al. 2016; Sankuro et al. 2018; Berhanu et al. 2014). The helminth parasites mentioned in this review were found in the gastrointestinal tracts of equids. In addition to helminths, various authors have documented protozoa infections ranging from 2.5 to 28.5% (Hagos et al. 2010a, b; Mekibib et al. 2010; Mkuria et al. 2010; Dagnachew et al. 2020). Furthermore, Ferede et al. (2010), Kumsa et al. (2012) and Tafese et al. (2014) found ectoparasite (tick and lice) infestations in equids ranging from 28.81 to 39.04%. As a result, it is possible to conclude that Ethiopia provided favourable environmental factors for the survival of various parasite species as well as their various stages.

According to the current meta-analysis, the weighted prevalence of parasitic infections in equids was 58.3%. The heterogeneity analysis using inverse variance indexes (I^2) revealed that real differences between studies accounted for 99% of the observed variance. The weighted prevalence estimates of parasitic infections in equids reported in this study differ from those reported by Khamesipour et al. (2021), who reported a pooled prevalence of 28.8%. Similarly, the current study's findings are higher than those reported in Greece (Kouam et al. 2010). This variation could be attributed to differences in study areas' agroecological features, study period, livestock management systems, diagnostic techniques used, sample size, and geographical location.

Helminths are common parasites in equids and pose serious health and performance issues in Ethiopia (Fikru et al. 2005; Getachew et al. 2010; Sheferaw and Alemu 2015; Mathewos et al. 2021a, b, 2022; Fesseha et al. 2022). These are known to be transmitted to their hosts through the consumption of infective larvae from contaminated pastures (Taylor et al. 2007). Helminth parasites affecting equids have been widely reported in various agro-climatic zones of Ethiopia. These parasites can be identified by a variety of clinical signs, including malaise, slowed growth, abdominal discomfort, diarrhoea, colic or abdominal pain, weakness, weight loss, decreased productivity, and death (Seyoum et al. 2015). In the current meta-analysis, the pooled prevalence estimate of helminths was found to be 77.1%. This is in line with reports from Ethiopia and other parts of the world (Valdéz-Cruz et al. 2013; Tedla and Abichu 2018; Mathewos et al. 2021a). The findings of Uslu and Guclu (2007) from Turkey, Maria et al. (2012) from India and Devkota et al. (2021) from Nepal are also comparable. Ogbein et al. (2022) from Nigeria reported findings similar to the current report. The current report also corroborates previous reports published elsewhere (Seyoum et al. 2015; Oli and Subedi 2018). However, studies in Ethiopia and Mexico estimate that endoparasite infections affect more than 90% of equids (Getachew et al. 2010; Ismail et al. 2016; Sankuro et al. 2018; Imam et al. 2021; Fesseha et al. 2022; Mathewos et al. 2022). The seasonality of the study period, management practises, sample size, topography, animal working conditions, sampling techniques, and climatic factors can all be attributed to the variations in the reports. Overall, based on our findings and previous research, we can conclude that the tropical environment of Ethiopia is conducive to helminth parasite transmission dynamics in equids.

Donkeys were the most affected equids with helminth parasites in the current study, followed by horses and mules. This supports previous studies (Seyoum et al. 2015; Belay et al. 2016; Imam et al. 2021; Mathewos et al. 2021a, b, 2022), which found that donkeys are more susceptible to helminth parasite infections than horses and mules. This variation among equids species could be attributed to the fact that donkeys in Ethiopia are subjected to poor management and a heavy workload, as well as fewer deworming practises (Getachew et al. 2008; Seyoum et al. 2015). It might make them more vulnerable to parasite infestation. Furthermore, this could be due to the relatively good trend of farmers' horse and mule management practises, which has become a routine activity of horse and mule owners due to economic reasons and owners' awareness of their horses' and mules' welfare. These points, however, need to be emphasised and investigated further.

Besides, despite the small number of studies, ectoparasites (ticks and lice) were found in Ethiopia (Ferede et al. 2010; Kumsa et al. 2012; Tafese et al. 2014). These

ectoparasites live as periodic or permanent parasites on their hosts' skin or skin surface, which can be harmful because they rely on their hosts for sustenance, maturation, and multiplication. Ticks and lice are a significant threat to cost-effective livestock production in many parts of the world, causing direct mechanical damage, anaemia, loss of condition, irritation, allergic reaction, toxicosis, morbidity, and mortality (Kumsa et al. 2012; Tafese et al. 2014). They are also indirectly involved in disease-causing pathogen transmission. Ticks, for example, have been identified as important vectors of animal diseases such as babesiosis, theileriosis, and anaplasmosis (Ferede et al. 2010; Kumsa et al. 2012). We observed tick-borne piroplasmiasis caused by *Theileria equi* and *Babesia caballi* in our review (Mekibib et al. 2010; Tefera et al. 2011; Gizachew et al. 2013; Getachew et al. 2014). Control of equids ectoparasites is thus critical for the protection of equids' health and an increase in their productivity in the country.

Ticks and lice have been found in all agro-ecological zones of Ethiopia (Kumsa et al. 2012; Tafese et al. 2014; Kaba 2022). S3Table shows the tick species found in equids in Ethiopia: *A. variegatum*, *A. gemma*, *R. decoloratus*, *R. e. evertsi*, *R. pulchellus*, *R. muhsame*, and *R. sanguineus* (Ferede et al. 2010; Kumsa et al. 2012; Kaba 2022). Similarly, the lice species infecting horses are *B. equi* and *H. asini* (Tafese et al. 2014). The overall pooled prevalence of ectoparasites was found to be 35.4% in this review. This corresponds to the findings of Gharbi et al. (2018) and Tramboos et al. (2019). Payne et al. (2017) from Cameroon, and Dik et al. (2020) from Turkey, on the other hand, reported a higher prevalence of ectoparasite infestation with a prevalence ranging from 91.8 to 99.66%. The differences in prevalence observed between studies could be attributed to differences in agro-climatic and geographical conditions, study area, species involved in the study, livestock management system, study period season, breed, and anti-parasitic medication availability.

This review included reports of equids trypanosomiasis and piroplasmiasis caused by *Trypanosoma* species and piroplasms, respectively. Pathogens are either intracellular or extracellular protozoans that live in the bloodstream of vertebrate hosts, causing anaemia, icterus, fever, anorexia, weight loss, infertility, and death (Alaba et al. 2022; Nimako-Boateng et al. 2022). Protozoans found in equids in Ethiopia included *Babesia caballi*, *Theileria equi*, *Trypanosoma vivax*, *T. brucei*, *T. congolense*, *T. evansi*, and *T. equiperdum*. *Trypanosoma equiperdum*, a trypanosome, is known to be sexually transmitted in equids, causing tissue destruction (Yasine et al. 2019). The weighted prevalence estimates of haemoparasites in our meta-analysis were 10.84%. This supports the findings of Mahmoud et al. (2016) and Alaba et al. (2022).

Conclusion

The present meta-analysis and systematic review demonstrated that equids parasite infection is frequent in Ethiopia and is caused by a variety of parasite species (helminths, protozoa, ectoparasites, and bot fly larvae), compromising the animals' health, welfare, and productivity. The pooled prevalence of parasite infection was found to be 58.3%. Helminths were the most frequent parasites detected in equids, accounting for 77.1%. Donkeys had the highest helminth parasite infection rates among equids. However, the reports made no attempt to identify the risk factors for parasite infection and infestation in equids in order to propose effective control strategies. The current study had also limitations because there were lacks of studies in some regions of the country and ectoparasite studies. Studies on ectoparasites and risk factor analysis are therefore advised. More emphasis should be placed on raising awareness about animal health and welfare.

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Declarations

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