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Prevalence and associated economic losses of bovine fasciolosis from postmortem inspection in municipal abattoirs in Ethiopia: A systematic review and meta-analysis

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ABSTRACT

Fasciolosis is a prevalent disease that significantly affects the health and productivity of cattle and causes significant economic loss. Beyond individually available studies with varying prevalence rates, there are no pooled national prevalence studies on bovine fasciolosis. Therefore, the aim of the current study was to determine the combined magnitude and economic significance of fasciolosis among cattle on postmortem examination. Inverse variance (I^2), sensitivity analysis, funnel plots, Begg's test, and Egger's regression test were used to assess heterogeneity and publication bias. A random-effects model was used to calculate the pooled burden of fasciolosis among cattle. The pooled prevalence of fasciolosis among cattle on postmortem examination was 31.77 % (95 % CI=27.82–35.71). Among a total of 14,965 livers of slaughtered cattle examined in municipal abattoirs, *Fasciola hepatica* (54.4 %) was the predominant fluke identified compared to *F. gigantica* (24.6 %). Mixed infections of both species and unidentified immature flukes were detected in 12.4 % and 7.6 %, respectively, of affected livers. Regarding the severity of the pathological lesions observed, 30.5 %, 44.3 %, and 25.2 % of the livers were lightly, moderately, and seriously infested, respectively. The pooled annual economic loss attributed to fasciolosis-associated liver condemnation among cattle in 40 reported studies was approximately 40,833,983.15 ETB (6,417, 847.73 USD). Therefore, bovine fasciolosis requires integrated control methods to address its influence on animal health and economic impact.

1. Introduction

Fasciolosis is a prevalent disease that significantly affects the health and productivity of ruminants (Yusuf et al., 2016). Two species of liver flukes (*Fasciola*) cause bovine fasciolosis: *Fasciola hepatica* and *Fasciola gigantica* and its hybrids (Abunna et al., 2010). *Fasciola hepatica*, whose intermediate host is *Lymnaea truncatula* has a cosmopolitan distribution in high-altitude, temperate, and cooler areas in tropical and subtropical areas, while *F. gigantica*, whose intermediate host is the *Lymnaea natalensis* is distributed widely in tropical regions (Legesse et al., 2017). Both species of *Fasciola* can infect humans inflicting harm on both the bile duct and liver tissue. The outcome of such damage manifests as inflammation, hepatomegaly, or liver cirrhosis, followed by anemia and diarrhea) (Nyirenda et al., 2019), and a wide range of domesticated animals, and wildlife. Compared to other animals, domestic ruminants such as cattle, sheep, and goats are more vulnerable to *Fasciola*. It causes hypertrophy and other pathological liver damage in infected ruminants, leading to condemnation of the liver during slaughter and significant financial loss to farmers and the livestock production industry (Jaja et al., 2017).

Fasciolosis is a disease of both veterinary and public health importance. It causes significant economic losses to global agriculture, estimated at $3 billion USD annually, through liver condemnation and reduction of milk and meat yields (Yatswako & Alhaji, 2017). According to Bekele and Getachew (2010), fasciolosis causes significant financial losses in many countries, including the UK and Ireland alone, where losses exceed £18 million annually. A Swiss study estimated that the disease causes losses of €52 million annually, or €299 per diseased animal, primarily from subclinical infection. In Kenya, liver condemnations in slaughtered cattle result in losses of approximately 0.26 million dollars annually. Additionally, scientists reported that cattle slaughtered at some Iringa, Tanzania, abattoirs had a high liver condemnation rate of

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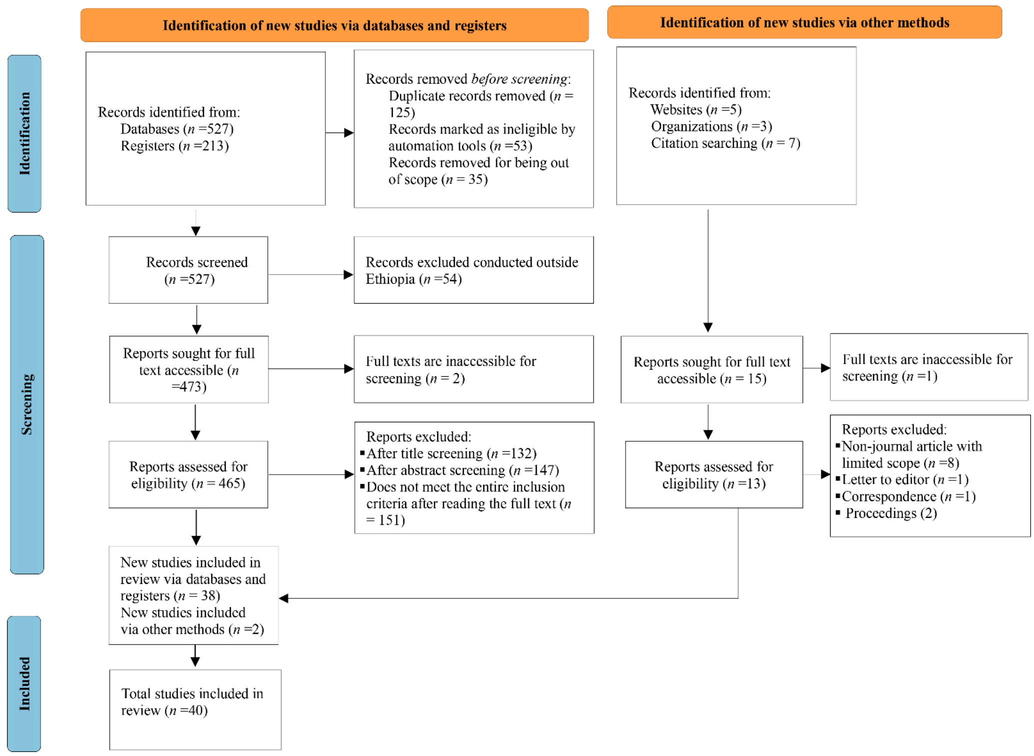

Fig. 1. PRISMA-2020 flow diagram of eligible studies.

up to 100 %. Furthermore, a recent study by the World Health Organization (WHO, 1995), revealed that 2.4 million people have fasciolosis and 180 million people are at risk of developing this illness. Officially, fasciolosis is recognized as a newly discovered human disease. Alemu (2019) reported that the global incidence of *Fasciola* infection in humans is expected to range from 2.4 to 1.7 million people, 180 million of whom are at risk.

Ethiopia's economy is based on agriculture, and *Fasciola* is widely distributed there (Yigezu Wendimu, 2021). According to other study conducted at Adwa municipal abattoir in North Ethiopia, the average annual financial loss resulting from condemnation of the liver due to fasciolosis was 4674.2 USD. Other researchers from Haramaya (Yusuf et al., 2016) and Wolaita Sodo (Zewde et al., 2019), Ethiopia, reported annual losses of $4414.523 and 43,024.458 USD, respectively, in liver condemnation associated with *Fasciola* in slaughtered cattle. It also poses a significant threat to the country's economy indirectly by reducing the number of laborers needed to track cattle, lowering milk and meat production, decreasing feed conversion efficiency, causing animals to die and become less fertile, and increasing treatment costs (Alemu, 2019; May et al., 2019; Jonsson et al., 2022; Wayessa et al., 2022).

Food safety concerns are compelling reasons for meat inspection and condemnation of infected liver. In this regard, the abattoir plays a crucial role not only in the detection and elimination of unhealthy meat from the food chain but also as a source of useful epidemiological data. Bovine fasciolosis is an animal and public health problem in Ethiopia. Except for individual studies with varying prevalence rates, there are no national prevalence studies conducted in abattoir settings in Ethiopia. Appropriate estimates of fasciolosis from postmortem inspection in abattoirs are essential to formulate health service plans most suitable for cattle. However, in Ethiopia, the prevalence of fasciolosis among cattle and the evaluation of its financial consequences are not collected, well organized, or recorded as a systematic review and meta-analysis. As a result, the objective of this study was to provide evidence on the overall prevalence and economic importance of fasciolosis among cattle using previously published research articles found in different regions of Ethiopia. The results obtained in the current investigation could also significantly benefit policymakers, development planners, and animal health practitioners.

2. Materials and methods

2.1. Search strategy

A systematic search of research articles was carried out in databases and registers (PubMed / Medline, Web of Science, ScienceDirect, EMBASE, Google Scholar, and ResearchGate), as well as other sources (websites, organizations, and citation search). The following key terms and phrases were used in combination or separately with Boolean operators ("OR" or "AND") to search the research articles: "prevalence", "epidemiology", "cattle", "bovine" "fasciolosis", "liver fluke", "*Fasciola*", "helminths", "autopsy", "postmortem inspection", "municipal abattoir" "economic significance" "financial loss" and "Ethiopia". The search strategy was implemented from September to November 2023.

2.2. Inclusion and exclusion criteria

The inclusion criteria were as follows: (a) studies followed a cross-sectional or both a cross-sectional and retrospective study design; (b) studies conducted in cattle; (c) studies conducted in Ethiopia; (d) municipal abattoir settings; (e) studies assessing postmortem examination; (f) studies published with full texts available for searches; (g) studies assessing associated economic/financial losses; (h) articles written in English or with an additional English translation was included; and (i) studies published between 2010 and 2023. The time restriction aimed to ensure that the findings reflected, or related to, the current state of bovine fasciolosis from postmortem inspection in Ethiopia.

The exclusion criteria were as follows: (i) reported the knowledge, attitudes, and practices of the municipal administrator or cattle husband about fasciolosis (qualitative studies); (ii) studies conducted outside of the municipal abattoir; and (iii) had published coprological

Table 1
General characteristics of the studies included in the systematic review and meta-analysis.

Study	Region	Study setting	Study design	Sampling method	Sample size	Cases	Postmortem inspection prevalence (95 % CI)	Financial Loss per annum	QS
(Abebe et al., 2010)	SNNPR	Hawassa municipal abattoir	CS	Simple random	3251	931	28.63 (23.3–34.7)	106, 400 ETB (8312.5 USD)	6
(Abunna et al., 2010)	SNNPR	Wolaita Soddo municipal abattoir	CS	Simple random	406	57	14 (9.8–20.2)	51,200 ETB (4000 USD)	6
(Bekele & Getachew, 2010)	Tigray	Adwa municipal abattoir	CS	Simple random	768	248	32.3 (27.4–38.3)	57,960 ETB (4674.2 USD)	6
(Wondwosen et al., 2012)	SNNPR	Wolaita Soddo municipal abattoir	CS	Systematic random	300	76	25.33 (20.2–31.7)	1574,482 ETB (87,471 USD)	5
(Nega et al., 2012)	Amhara	Gondar ELFORA abattoir	CS& RS	Simple random	400	119	29.75 (24.8–35.8)	32, 075.41 ETB (2566 USD)	5
(Regassa et al., 2012)	Oromia	Bishooftu municipal abattoir	CS	Simple random	1151	249	21.6 (16.5–27.8)	232,232 ETB (13,364.72USD)	6
(Belay et al., 2012)	Amhara	Dessie municipal abattoir	CS	Simple random	500	126	25.2 (20.3–31.5)	2495, 346.13 ETB (143,604.68 USD)	6
(Demssie et al., 2012)	Oromia	Jimma municipal abattoir	CS	Systematic random	382	208	54.5 (49.4–60.6)	2570,396 ETB (151,200 USD)	6
(Terefe et al., 2012)	Oromia	Jimma municipal abattoir	CS	Systematic random	761	407	53.48 (48.5–59.6)	3003,488.1408 ETB (172,847.75 USD)	6
(Equar et al., 2012)	Tigray	Mekelle municipal abattoir	CS	Simple random	1000	352	35.2 (30.1–42.3)	224,539.20 (2245 USD)	6
(Sisay & Nibret, 2013)	Amhara	Bahir Dar municipal abattoir	CS	Systematic random	384	174	45.3 (40.2–51.4)	198,457.80 ETB (11,421.61 USD)	6
(Kebede et al., 2013)	Amhara	Gondar Elfora abattoir	CS	Simple random	402	97	24.13 (19.1–30.3)	2910.80 (300 USD)	6
(Petros et al., 2013)	Oromia	Nekemte municipal abattoir	CS	Systematic	384	84	21.9 (16.9–28.1)	63,072 ETB (1182,600 USD).	6
(Mebrahtu & Beka, 2013)	Dire Dawa	Dire Dawa municipal abattoir	CS&RS	Simple random	450	110	24.44 (19.3–30.5)	2029,872.10 ETB (124,151.2 USD).	5
(Asrese & Ali, 2014)	SNNPR	Wolaita Soddo municipal abattoir	CS	Simple random	384	78	20.3 (15.3–26.7)	3711,246 ETB (201,111.5 USD)	6
(Fetene & Addis, 2014)	Amhara	Dangila municipal abattoir	CS	Simple random	384	116	30.21 (25.3–36.7)	945,270 ETB (48, 431 USD)	6
(Zeleke et al., 2014)	Oromia	Mettu municipal abattoir	CS &RS	Simple random	663	312	47.1 (42.1–53.2)	513,720.00 ETB (51,372.00 USD)	5
(Yitagezu et al., 2015)	Oromia	Bedele municipal abattoir	CS	Simple random	455	148	32.53 (27.6–37.8)	228,360.6 ETB (13,591 USD)	6
(Alemu & Abebe, 2015)	SNNPR	Wolaita Soddo municipal abattoir	CS	Simple random	500	143	26.8 (21.8–32.8)	3564,990.00 ETB (187,631.053 USD)	6
(Nebyou et al., 2015)	SNNPR	Areka municipal abattoir	CS	Systematic random	400	120	30 (24.9–36.1)	47,124 ETB (24,06.74 USD)	6
(Girmay et al., 2015)	Tigray	Hawzien municipal abattoir	CS	Simple random	215	46	21.39 (16.4–27.6)	885,500 ETB (45,224.69 USD)	5
(Abebe et al., 2016)	SNNPR	Bonga municipal abattoir	CS	Systematic random	384	63	16.4 (11.4–22.6)	66,420 ETB (33,92.23 USD)	6
(Amsalu et al., 2017)	SNNPR	Hawassa municipal abattoir	CS	Systematic random	316	101	31.96 (26.9–38.1)	291,635.00 ETB (12,495.07 USD)	6
(Oyda et al., 2017)	SNNPR	Wolaita Soddo municipal abattoir	CS	Systematic random	415	127	30.6 (25.6–36.8)	115,362 ETB (4942.67 USD)	5
(Eshetu et al., 2017)	SNNPR	Angacha municipal abattoir	CS	Systematic random	384	156	40.62 (35.6–46.8)	48,744.00 ETB (2565.47 USD)	6
(Getahun et al., 2017)	SNNPR	Hossana municipal abattoir	CS	Simple random	422	115	27.25 (22.2–33.5)	66,370.10 ETB (3493.16 USD)	6
(Meaza et al., 2017)	SNNPR	Arba Minch municipal abattoir	CS	Systematic random	600	203	33.83 (28.8–40.1)	726,561.5 ETB (52,649.38 USD)	6
(Wolde & Tamiru, 2017)	SNNPR	Wolkite town, community abattoir	CS	systematic random	392	164	41.8 (36.8–47.9)	5,167,081.92 ETB (240,329 USD)	6
(Worku et al., 2017)	Oromia	Assela municipal abattoir	CS	Systematic random	349	105	30.1 (25.1–36.3)	20,00,506.2 ETB (85,711.50 USD)	5
(Ayelign & Alemneh, 2017)	Amhara	Kombolcha ELFORA abattoir	CS	Simple random	380	205	53.97 (48.9–60.1)	1601,776.71 ETB (68,627.97 USD)	5
(Ayele et al., 2018)	Amhara	Debire Birhan municipal abattoir	CS	Simple random	300	176	58.6 (53.5–64.7)	59,387 ETB (2969 USD)	5
(Mohammadnur & Geleta, 2018)	Oromia	Robe Municipal Abattoir	CS	Simple random	502	345	68.72 (63.7–74.9)	2935,670.4 ETB (108,728.5 USD).	6
(Zewde et al., 2019)	SNNPR	Wolaita Soddo municipal abattoir	CS	Systematic random	247	50	20.24 (15.3–26.5)	1505, 856 ETB (43, 024.458 USD)	5
(Bekele, 2019)	Oromia	Lalo municipal abattoir	CS	Systematic random	412	120	29.13 (24.1–35.3)	92, 851.86 ETB (3438.95 USD)	6
(Kassie & Ali, 2019)	Amhara	Gondar ELFORA abattoir	CS	systematic random	384	90	23.4 (18.4–29.5)	1919,640 ETB (65,922 USD).	6

(continued on next page)

Table 1 (*continued*)

Study	Region	Study setting	Study design	Sampling method	Sample size	Cases	Postmortem inspection prevalence (95 % CI)	Financial Loss per annum	QS
(Mequaninit & Mengesha, 2021)	Amhara	Kombolcha industrial abattoir	CS & RS	Simple random	409	143	35 (30.0–41.0)	72,360 ETB (3206,995.2 USD)	6
(Fesseha & Asefa, 2022)	SNNPR	Wolaita Sodo municipal abattoir	CS	Systematic random	384	52	13.54 (8.5–20.1)	242,990 ETB (4944.03 USD)	6
(Japaro, 2023)	SNNPR	Gesuba municipal abattoir and district municipal abattoirs of Kawo koyisha (Lasho) and Bayira koyisha (Baliko sagno)	CS	Simple random	400	58	14.5 (9.5–20.7)	5614,657.68 ETB (80,209.40 USD)	6
(Mathewos et al., 2023)	SNNPR	Tarcha municipal abattoir	CS	Simple random	384	115	29.94 (24.9–36.1)	2227,536 2, ETB (47,945.24 USD)	6
(Tadesse & Acklock, 2023)	SNNPR	Yirgalem municipal abattoir	CS	Systematic random	400	108	27.0 (22.0–33.0)	945, 999 ETB (18,192.288 USD)	6

SNNPR, Southern Nations, Nationalities, and People's Region; *CS*, cross-sectional; *RS*, retrospective study; QS, quality score.

examinations only; (iv) articles with insufficient information or records with missing outcomes of interest; (v) personal opinions, correspondence, letters to the editor, proceedings, and reviews.

2.3. Study screening and selection

To avoid duplications, all of the identified studies were imported to the EndNote X8 citation manager (Thomson Reuters, USA) and then assessed for eligibility to be included in this systematic review and meta-analysis using a prepared Microsoft Excel assessment format. The titles and abstracts of studies retrieved and those from additional sources were screened to identify studies that satisfy the inclusion criteria. Then, the full text of potentially eligible studies was assessed.

2.4. Data extraction

The data extraction process was carried out following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA-2020) guidelines as recommended by Page et al. (2021). The studies were evaluated, and the necessary data were extracted independently by four researchers (AmG, KT, IA, and DT) following the inclusion and exclusion criteria using a standardized data extraction format in an Excel spreadsheet in 2021. The following information was extracted from the studies: study (first author and publication year), study region, study setting, study design, sampling method, sample size, cases, prevalence (postmortem examination), and financial loss per year. When the four authors disagreed, a fifth author (AbG) was consulted and disagreements were resolved by consensus and discussion.

2.5. Quality assessment tool

The overall quality of the evidence was evaluated using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) tool (Atkins et al., 2004). To determine the quality of each study, the tool contains three main evaluation instruments: methodological quality, comparability, and statistical analysis and research results. Each criterion received two points. Publications receiving a total score of 0 to 3 points were considered low-quality publications; 4 points were considered medium-quality publications; and 5 to 6 points were considered high-quality publications. AbG and DT., two reviewers, independently selected the articles and evaluated their quality. Once a consensus was reached, articles were added, and differences between reviewers were settled through discussion.

2.6. Outcomes

The outcomes of this systematic review and meta-analysis are the pooled prevalence of bovine fasciolosis from postmortem inspections in Ethiopian municipal abattoirs. The pooled causative agents of fasciolosis in Ethiopian municipal abattoirs and the severity of the infection are investigated. We also pooled the annual economic significance of fasciolosis among cattle associated with liver condemnation in Ethiopian municipal abattoirs.

2.7. Data analysis

The data were exported to STATA software version 14 for analysis after all pertinent findings had been extracted and placed in Microsoft Excel 2021. A 95 % confidence interval was used to calculate the pooled prevalence of fasciolosis. The funnel plot and Begg and Egger regression tests were used to detect publication bias, with a p-value of less than 0.05 indicating statistical significance (Begg & Mazumdar, 1994; Egger et al., 1997; Sterne & Egger, 2001). I^2 was used to quantify the degree of heterogeneity between studies; values of 25, 50, and 75 % indicated moderate, medium, and high heterogeneity, respectively (Higgins & Thompson, 2002; Rücker et al., 2008). Random-effect model analysis was used to estimate the overall prevalence of fasciolosis, and a forest plot was generated to visually assess the presence of heterogeneity, which presented at a high level (Borenstein et al., 2010). Subgroup analysis was conducted based on region, publication year, sampling method, and sample size to identify potential sources of heterogeneity. Sensitivity analysis (using Duval and Tweedie's Trim and Fill analysis in the random effect model) (Rücker et al., 2008) was used to investigate how one study affected the overall prevalence of fasciolosis in the meta-analysis.

3. Results

3.1. Studies included

In total, 755 articles on the prevalence of fasciolosis and associated economic losses were recovered from Ethiopia. A total of 213 records were removed before screening (duplicate records removed ($n = 125$), records marked as ineligible by automation tools ($n = 53$), and records removed because they were outside the scope ($n = 35$)). Of the remaining 542 articles, 54 and 3 studies conducted outside Ethiopia and full text inaccessible for screening were further excluded. Of the 485 articles, 445 were further excluded after title, abstract, and full text screening following the inclusion and exclusion criteria used. Finally, 40 articles were included as per the inclusion and exclusion criteria used for the current systematic review and meta-analysis (Fig. 1).

3.2. Characteristics of the included studies

In this systematic review and meta-analysis, 36 studies employed a cross-sectional study design, and the remaining 4 studies used both a

Table 2
Fasciola species infecting the livers of slaughtered cattle in municipal abattoirs.

Fasciola species encountered	Frequency (n)	Percentage (%)	Included studies
Fasciola hepatica	3775	55.4	(Abebe et al., 2010; Abunna et al., 2010; Bekele & Getachew, 2010; Belay et al., 2012; Demssie et al., 2012; Equar et al., 2012; Nega et al., 2012; Regassa et al., 2012; Terefe et al., 2012; Wondwosen et al., 2012; Kebede et al., 2013; Mebrahtu & Beka, 2013; Petros et al., 2013; Sisay & Nibret, 2013; Asrese & Ali, 2014; Fetene & Addis, 2014; Zeleke et al., 2014; Alemu & Abebe, 2015; Girmay et al., 2015; Nebyou et al., 2015; Yitagezu et al., 2015; Abebe et al., 2016; Amsalu et al., 2017; Ayelign & Alemneh, 2017; Eshetu et al., 2017; Getahun et al., 2017; Meaza et al., 2017; Oyda et al., 2017; Wolde & Tamiru, 2017; Worku et al., 2017; Ayele et al., 2018; Mohammadnur & Geleta, 2018; Bekele, 2019; Kassie & Ali, 2019; Zewde et al., 2019; Mequaninit & Mengesha, 2021; Fesseha & Asefa, 2022; Japaro, 2023; Mathewos et al., 2023; Tadesse & Acklock, 2023)
Fasciola gigantica	1674	24.6	(Abebe et al., 2010; Abunna et al., 2010; Bekele & Getachew, 2010; Belay et al., 2012; Demssie et al., 2012; Equar et al., 2012; Nega et al., 2012; Regassa et al., 2012; Terefe et al., 2012; Wondwosen et al., 2012; Kebede et al., 2013; Mebrahtu & Beka, 2013; Petros et al., 2013; Sisay & Nibret, 2013; Asrese & Ali, 2014; Fetene & Addis, 2014; Zeleke et al., 2014; Alemu & Abebe, 2015; Girmay et al., 2015; Nebyou et al., 2015; Yitagezu et al., 2015; Abebe et al., 2016; Amsalu et al., 2017; Ayelign & Alemneh, 2017; Eshetu et al., 2017; Getahun et al., 2017; Meaza et al., 2017; Oyda et al., 2017; Wolde & Tamiru, 2017; Worku et al., 2017; Ayele et al., 2018; Mohammadnur & Geleta, 2018; Bekele, 2019; Kassie & Ali, 2019; Zewde et al., 2019; Mequaninit & Mengesha, 2021; Fesseha & Asefa, 2022; Japaro, 2023; Mathewos et al., 2023; Tadesse & Acklock, 2023)
Mixed infections by both species	847	12.4	(Abebe et al., 2010; Abunna et al., 2010; Bekele & Getachew, 2010; Belay et al., 2012; Demssie et al., 2012; Equar et al., 2012; Nega et al., 2012; Regassa et al., 2012; Terefe et al., 2012; Wondwosen et al., 2012; Kebede et al., 2013; Mebrahtu & Beka, 2013; Petros et al., 2013; Sisay & Nibret, 2013; Asrese & Ali, 2014; Fetene & Addis, 2014; Zeleke et al., 2014; Alemu & Abebe, 2015; Nebyou et al., 2015; Yitagezu et al., 2015; Abebe et al., 2016; Amsalu et al., 2017; Ayelign & Alemneh, 2017; Eshetu et al., 2017; Getahun et al., 2017; Meaza et al., 2017; Wolde & Tamiru, 2017; Worku et al., 2017; Ayele et al., 2018; Bekele, 2019; Kassie & Ali, 2019; Mequaninit & Mengesha, 2021; Japaro, 2023; Tadesse & Acklock, 2023)
Unidentified immature flukes	521	7.6	(Abebe et al., 2010; Abunna et al., 2010; Bekele & Getachew, 2010; Belay et al., 2012; Demssie et al., 2012; Equar et al., 2012; Terefe et al., 2012; Wondwosen et al., 2012; Mebrahtu & Beka, 2013; Sisay & Nibret, 2013; Asrese & Ali, 2014; Fetene & Addis, 2014; Zeleke et al., 2014; Alemu & Abebe, 2015; Abebe et al., 2016; Amsalu et al., 2017; Getahun et al., 2017; Wolde & Tamiru, 2017; Ayele et al., 2018; Bekele, 2019; Mequaninit & Mengesha, 2021; Fesseha & Asefa, 2022; Tadesse & Acklock, 2023)
Severity of infection	**Frequency (n)**	**Percentage (%)**	**Included studies**
Lightly	995	30.5	(Abebe et al., 2010; Bekele & Getachew, 2010; Equar et al., 2012; Terefe et al., 2012; Sisay & Nibret, 2013; Amsalu et al., 2017; Meaza et al., 2017; Worku et al., 2017; Ayele et al., 2018; Mohammadnur & Geleta, 2018; Alemu, 2019; Tadesse & Acklock, 2023)
Moderately	1447	44.3	
Severely	823	25.2	

cross-sectional and a retrospective study design. Eighteen studies were conducted in the Southern Nations Nationalists and Peoples Region (SNNPR), nine each in the Amhara and Oromia regions, three in the Tigray region, and one in the Dire Dawa. The sample sizes of the studies ranged from 215 to 3251, and the prevalence rates of fasciolosis within the studies ranged from 14.0 to 68.72 %. This systematic review and meta-analysis included a total of 21,004 cattle slaughtered at municipal abattoirs. All studies were assessed using the tools of GRADE and yielded low risk scores (Table 1).

3.3. Causative agents and severity of fasciolosis among cattle

From the published data included in the current systematic review and meta-analysis, pathology was also performed on a total of 21,004 livers of slaughtered cattle in municipal abattoirs to determine the causative agents of fasciolosis in Ethiopia. The pooled prevalence of *Fasciola hepatica, Fasciola gigantica*, mixed infections caused by both species, and unidentified immature flukes were 55.4, 24.6, 12.4, and 7.6 %, respectively (Table 2). Regarding the severity of the pathological lesions observed, 30.5 % (995/3265), 44.3 % (1447/3265) and 25.2 %

Table 3
Subgroup analysis of the magnitude of fasciolosis among cattle.

Variables	Characteristics	Included studies	Sample size	Prevalence (95 % CI)	I^2, P–value
Sample size	<400	18	6337	32.20 (95 % CI: 25.82, 38.58)	95.7, *P* < 0.001
	≥400	22	14,667	31.41 (95 % CI: 26.36, 36.47)	94.5, *P* < 0.001
Region	SNNPR	18	9969	26.26 (95 % CI: 22.34, 30.18)	88.7, *P* < 0.001
	Tigray	3	1983	29.58 (95 % CI: 21.37, 37.80)	83.9, *P* = 0.002
	Amhara	9	3543	36.17 (95 % CI: 27.52, 44.83)	95.4, *P* < 0.001
	Oromia	9	5059	39.89 (95 % CI: 29.15, 50.63)	97.1, *P* < 0.001
	Dire Dawa	1	450	24.44 (95 % CI: 18.84, 30.04)	–, –
Sampling method	Simple random	22	13,726	31.89 (95 % CI: 26.11, 37.66)	95.8, *P* < 0.001
	Systematic random	18	7278	31.62 (95 % CI: 26.26, 36.99)	93.9, *P* < 0.001
Publication Year	2010–2014	17	11,970	31.37 (95 % CI: 25.63, 37.11)	94.4, *P* < 0.001
	2015–2019	18	7057	34.30 (95 % CI: 27.94, 40.65)	95.7, *P* < 0.001
	2020–2023	5	1977	24.02 (95 % CI: 15.68, 32.35)	91.0, *P* < 0.001
	Overall	40	21,004	31.77 (95 % CI: 27.82, 35.71)	95.0, *P* < 0.001

SNNPR, Southern Nations, Nationalities, and People's Region.

(823/3265) of the livers were mildly, moderately, and seriously infested, respectively (Table 2).

3.4. Meta-analysis

The pooled prevalence of fasciolosis among cattle in Ethiopia is presented in the forest plots in Fig. 2. A random effects model showed that the pooled prevalence of fasciolosis among cattle was 31.77 % (95 % CI=27.82–35.71; I^2=95.0 %).

3.5. Subgroup analysis

A sample size of less than 400 with a pooled prevalence of 32.20 % (95 % CI: 25.82, 38.58) was comparatively greater than that of its counterparts (a sample size greater than or equal to 400), with a pooled prevalence of 31.41 % (95 % CI: 26.36, 36.47) (Table 3). With respect to region, 39.89 % (95 % CI: 29.15, 50.63), 36.17 % (95 % CI: 27.52, 44.83), 29.58 % (95 % CI: 21.37, 37.80), 26.26 % (95 % CI: 22.34, 30.18), and 24.44 % (95 % CI: 18.84, 30.04) were the pooled prevalence of bovine fasciolosis in Oromia, Amhara, Tigray, SNNPR, and Dire Dawa, respectively (Table 3). Regarding the sampling technique, the pooled prevalence of bovine fasciolosis was higher in the simple random sampling method (31.89, 95 % CI: 26.11, 37.66) than in the systematic random sampling method (31.62, 95 % CI: 26.26, 36.99) (Table 3). The estimate of bovine fasciolosis prevalence was higher between 2015 and 2019, with a pooled prevalence estimate of 34.30 % (95 % CI: 27.94, 40.65) than in the study period 2010 to 2014, at 31.37 % (95 % CI: 25.63, 37.11), and from 2020 to 2023, at 24.02 % (95 % CI: 15.68, 32.35) (Table 3). The prevalences in all subgroup analysis showed significant heterogeneity (Table 3).

3.6. Heterogeneity, publication bias, and sensitivity analysis

All heterogeneity and publication bias of the included studies were evaluated, and high levels of heterogeneity were present ($I^2 = 95.0$ %, $p < 0.001$). The funnel plot revealed an asymmetrical distribution (Fig. 3). The Egger and Begg tests revealed that there was no substantial publication bias. To clarify the impact of each study on the size of the pooled effect, a sensitivity analysis was performed by removing each study one at a time. According to sensitivity analysis, almost all studies had no determinant effects on the overall magnitude of fasciolosis among cattle in Ethiopia, except the study conducted by Mohammadnur and Geleta (2018).

3.7. Pooled assessment of financial loss associated with liver condemnation

The parasite *Fasciola* activity damages the liver and leads it condemnation. The annual economic loss associated with the condemnation of the liver owing to the damage caused by bovine fasciolosis among cattle was determined from 40 studies, with a pooled estimate of 40,833,983.15 ETB (6417, 847.73 USD).

4. Discussion

The pooled prevalence of bovine fasciolosis obtained by postmortem examination of the cattle (31.77 %) was consistent with the previous reports of 27.68 % in Nigeria (Magaji et al., 2014), 30.88 % in Egypt (Elshraway & Mahmoud, 2017), and 33.2 % in Burundi (Nkurunziza et al., 2024). However, it was lower than the reports of 43.63 % in Pakistan (Rehman, 2013), 64.4 % in Zambia (Nyirenda et al., 2019), and 65.7 % in Uganda (Opio et al., 2021). However, these findings exceeded the reports of 19 % in South Sudan (Nigo et al., 2019), 16.3 % in Saudi Arabia (Degheidy & Al-Malki, 2012), 15.1 % in Brazil (Américo et al., 2022), 13.04 % in Burundi (Minani et al., 2023), 13.5 % in Nigeria (Okonkwo et al., 2023), 12.3 % in Rwanda (Habarugira et al., 2016), and 8 % in Algeria (Hamiroune et al., 2020). This disparity in prevalence could be due to variations in ecology, climate, and management practices and may have affected vector, parasite epidemiology, and risk of infection.

In this study, postmortem examination of pooled diseased livers of cattle from different municipal abattoirs revealed that *F. hepatica* was the dominant species (54.73 %), followed by *F. gigantica* (23.21 %), mixed infection (15.04 %) and immature flukes (7.02 %). Current data support the findings of (Ngele & Ibe, 2014; Khademvatan et al., 2019), who claimed that the most common species of liver fluke that infects cattle was *F. hepatica*. However, the results of the present study did not agree with earlier research carried out elsewhere (Nyirenda et al., 2019; Ahmad et al., 2020), which reported *F. gigantica* is the commonest species of liver fluke that affects cattle. The surrounding ecosystem, which supports the growth of snails, intermediate hosts of both parasite species, may be the cause of this disparity (Urquhart et al., 1996).

In the present 40 included studies, the total economic loss caused by bovine fasciolosis was calculated on the basis of the liver's condemnation for fasciolosis-inflicted abnormalities. All fasciolosis-inflicted liver defects were condemned in the abattoir as unfit for human consumption. According to estimates, the annual direct economic loss resulting from fasciolosis-related liver condemnation was 40,833,983.15 ETB (6417,847.73 USD) on average. A similar study in Iran reported a relatively consistent estimate of 5110,499 USD loss (Jahed Khaniki et al., 2013). This figure was higher than that of prior figures in Rwanda 8932.40 USD (Habarugira et al., 2016), Saudi Arabia 20,000 USD (Degheidy & Al-Malki, 2012), Pakistan 35,697 USD (Rehman, 2013),

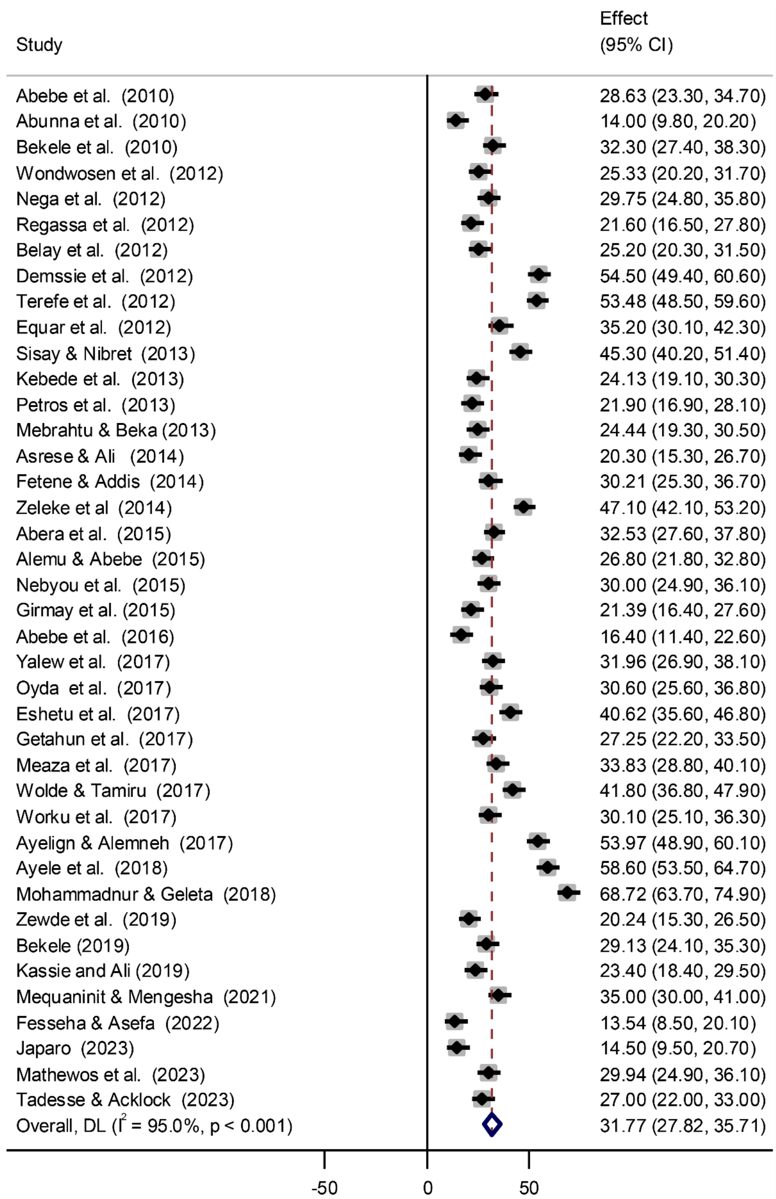

Fig. 3. Funnel plot presentation, an indication of publication bias among included studies that estimates fasciolosis from postmortem inspection in Ethiopia.

Zambia 592,560 USD (Nyirenda et al., 2019), Nigeria 776,832 USD (Yatswako & Alhaji, 2017), and Kenya 2567,586 USD (Kithuka et al., 2002). The differences in the losses reported in this study and others may be attributed to different abattoir slaughter capacities, estimation methodologies, sampling techniques, and livestock populations. Other reasons may be variations in prevalence, climatic conditions, and the productivity of animals and prices (Jaja et al., 2017).

Limitations, strengths and future directions of the study

The current study has certain limitations. The prevalence and financial losses in Ethiopia due to fasciolosis could have been underreported since a significant proportion of cattle are slaughtered informally. The risk factors for fasciolosis were also not included due to the fact that the majority of original articles did not report the necessary data to pool and analyze. It was also challenging to generalize the results due to a lack of information and data from other regions of Ethiopia. This work is the first report conducted on the pooled prevalence of bovine fasciolosis and its financial loss due to liver condemnation from the postmortem inspection in Ethiopia. Therefore, the current work is very crucial for researchers and respective bodies to re-examine the current comprehensive epidemiological data and use it as a base line to conduct other research and prepare fasciolosis control guidelines at the country level. This study also encourages the researchers to conduct bovine fasciolosis and financial loss survey in the municipal abattoirs of the remaining regions (Afar, Somali, Harari, Benishangul-Gumuz, and Gambella) and city administration (Addis Ababa) of Ethiopia.

5. Conclusion and recommendations

The current study revealed that bovine fasciolosis was quite prevalent. This led to a large amount of liver damage and condemnation, which had a negative financial impact on the animal production industry and caused losses for livestock farmers. The prevalence of *Fasciola* reported in the current study also portends great danger for public health. Hence, its potential as a re-emerging zoonosis should not be overlooked. Due to the higher prevalence rate of this disease, control and prevention measures are needed to combat the infection and its subsequent economic and health impacts. These measures include managing grazing, reducing the number of intermediate hosts, and diagnosing and treating sick animals with anthelmintics.

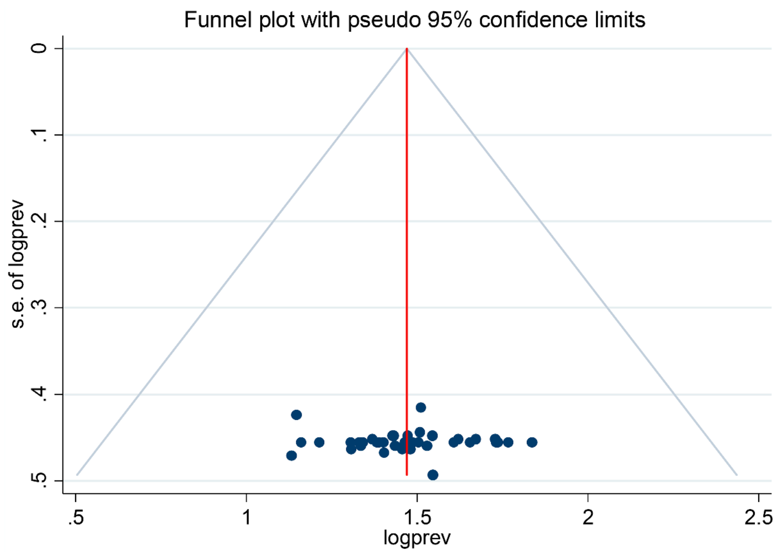

Fig. 2. Forest plot of the prevalence of fasciolosis among cattle in Ethiopia.

Ethics approval and consent to participate

Formal consent or ethics approval was not needed for this study.

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CRediT authorship contribution statement

Abayeneh Girma: Conceptualization, Software, Formal analysis, Investigation, Validation, Visualization, Project administration, Supervision, Writing – review & editing. **Kasaye Teshome:** Methodology, Resources, Data curation, Validation, Visualization, Writing – original draft. **Indris Abdu:** Methodology, Resources, Data curation, Validation, Visualization, Writing – original draft. **Amere Genet:** Methodology, Resources, Data curation, Validation, Visualization, Writing – original draft. **Dessalew Tamir:** Methodology, Resources, Data curation, Validation, Visualization, Writing – original draft.

Declaration of competing interest

The authors declare that they have no competing interests.

Data availability

The generated data sets are available from the corresponding author on request.

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