



Research article

Prevalence of coccidiosis in small ruminants in Indonesia: a systematic review and meta-analysis

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Abstract

Coccidiosis is a frequently occurring disease in small ruminants. However, comprehensive estimates of its burden in Indonesia remain limited. This study conducted a systematic review and meta-analysis following PRISMA guidelines to estimate the pooled prevalence of *Eimeria* infection in Indonesian small ruminants. A systematic literature search was conducted across three databases. Eligible studies reporting the prevalence of *Eimeria* infection in small ruminants were included. A random-effects model was applied to estimate the pooled prevalence. In addition, subgroup, meta-regression, and sensitivity analyses were conducted to investigate sources of heterogeneity. A total of 12 studies met the inclusion criteria. The pooled prevalence of coccidiosis in Indonesian small ruminants was 48.99% (95% CI: 26.23–72.17). High heterogeneity was detected ($I^2 = 97\%$), suggesting substantial variability among studies. Subgroup analysis revealed significantly higher prevalence in goats (68.68%) compared to sheep (15.84%) ($p < 0.01$), while no significant differences were observed across provinces ($p = 0.35$). The meta-analysis of risk factors showed no significant association for sex (OR = 0.99; $p = 0.95$) or age (OR = 2.77; $p = 0.06$). Meta-regression indicated no temporal trend in prevalence ($p = 0.99$). Sensitivity analysis confirmed the robustness of the findings, although publication bias was detected. In conclusion, coccidiosis remains highly prevalent in small ruminants in Indonesia, particularly in goats. These findings highlight the need for strengthened surveillance and effective control strategies.

Keywords: *Eimeria* spp., Goats, Indonesia, Sheep, Small ruminants.

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INTRODUCTION

Coccidiosis is one of the most common parasitic infestations in small ruminants, with a significant impact on livestock health and productivity, especially in tropical and subtropical regions (Rana, 2024). This is an economically important parasitic disease worldwide, affecting animal productivity and welfare (Chartier and Paraud, 2012; Hung et al., 2025). These parasites belong to the genus *Eimeria*, which are intracellular parasites that infect epithelial cells in the digestive tract (Engidaw et al., 2015). The general clinical effects of coccidiosis include uneven lamb size, a higher feed conversion ratio, and even a reduction in weight gain (Odden et al., 2017). Furthermore, symptoms caused by *Eimeria* infection include bleeding diarrhea and feces containing blood, epithelial tissue, and mucosa, depending on the severity of infection (Bangoura and Bardsley, 2020). Small ruminants are susceptible to coccidiosis at 4–6 months of age, with clinical effects including dehydration, digestive disorders, and lethargy (Hamid et al., 2021).

The majority of the *Eimeria* genus, which consists of approximately 1,700 species, are host-specific or monoxenous (López-Osorio et al., 2020). This reflects the strict host specificity of most *Eimeria* species. The most pathogenic *Eimeria* species for goats are *E. ninakohlyakimovae* and *E. arloingi*. In sheep, pathogenic species include *E. crandallii*, *E. ahsata*, and *E. ovinoidalis*, which develop in the large intestine and are considered the most pathogenic species causing coccidiosis (Chartier and Paraud, 2012). Gastrointestinal protozoan infestation with *Eimeria* spp. is usually a mixed infestation involving several species. The most pathogenic infestations in goats or sheep are caused by *E. arloingi* and *E. ninakohlyakimovae*, which can cause severe clinical symptoms such as diarrhea, anorexia, weakness, weight loss, and infections in the digestive tract (jejunum, ileum, and cecum) due to the lesions that develop and spread in the intestinal epithelium, and even death (Cepeda-Palacios et al., 2015). Identification of *Eimeria* spp. is generally performed using microscopic examination by analyzing the morphology of sporulated oocysts, including oocyst residue, size, sporulation time, polar cap, and microfilaments (Rotolo et al., 2023; Mohammed et al., 2024; Reshi et al., 2025). This method is considered to have limitations in terms of sensitivity, time requirements, and dependence on laboratory technician skills, thus molecular methods such as internal transcribed spacer-1 (ITS-1) and 18S rDNA sequencing have been introduced as a solution to the limitations of the previous methods (Hassanen et al., 2020).

The goat population in Indonesia reached 15,710,055, while the sheep population reached 9,219,176 (BPS-Statistics Indonesia, 2024). The average prevalence of *Eimeria* spp. based on several studies in Java (Banten, West Java, Central Java, Yogyakarta, East Java) ranges from 89–100% (Dewi et al., 2025); in Sumatra, which includes North Sumatra at 85–100% and Lampung at 70% (Napitupulu and Tanjung, 2022; Pertiwi et al., 2023). The results of a systematic review and meta-analysis of coccidiosis in cattle in Indonesia showed that the pooled prevalence of the disease reaches approximately 37.3% (95% CI: 23.2–51.4) (Ninditya, 2024). However, no systematic review or meta-analysis has been specifically conducted on the prevalence of coccidiosis in small ruminants in Indonesia. Therefore, this study aimed to estimate the prevalence of coccidiosis in small ruminants in Indonesia.

MATERIALS AND METHODS

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2015). The research protocol was registered on the Open Science Framework (OSF; <https://osf.io/z6mtk/files/3xnq6>). The systematic review and meta-analysis were carried out from August 2025 to October 2025. Data extraction was performed at

the Vocational College, Universitas Gadjah Mada, Yogyakarta, Indonesia. PubMed, Scopus, and Google Scholar databases were systematically searched for the literature using search terms related to “*Eimeria*”, “Indonesia”, “prevalence”, “goat”, and “sheep”. Boolean operators “AND” and “OR” were applied to systematically combine or separate the selected keywords.

Selection criteria

Studies were selected for inclusion in the systematic review and meta-analysis based on the following eligibility criteria: (1) reporting the prevalence of *Eimeria*, (2) published in English or Bahasa Indonesia, (3) designed as cross-sectional or observational studies, and (4) conducted on small ruminants. In addition, articles were required to include specific information on the type of samples collected, the diagnostic methods used, and the sample size to be considered for inclusion. However, experimental, cohort, and case-control studies were excluded from the analysis. The specific screening guidelines applied in this review are detailed in the study protocol. All retrieved articles were thoroughly assessed using the Rayyan Intelligent Systematic Review platform (www.rayyan.ai) to identify duplicates and screen studies, ensuring the integrity of the review process. Two independent reviewers screened the manuscripts based on title and abstract.

Data extraction

Data were extracted by the first reviewer and subsequently reviewed by the second reviewer. In cases of disagreement between reviewers, the issue was resolved through discussion until a consensus was reached. The extracted data included the authors' names, year of publication, animal species, sample size, sample origin, study location, diagnostic method, and the number of *Eimeria* cases identified. All data were collected and organized into pre-designed Microsoft Excel sheets (Microsoft Corp., Redmond, WA, USA).

Statistical analysis for pooled prevalence and subgroup analysis

Statistical analysis was performed using R 4.3.1 software (Comprehensive R Archive Network, Vienna, Austria) using the “meta” and “metafor” packages (Schwarzer, 2022). Forest plots were generated to present the pooled prevalence estimates with 95% confidence intervals (CI). Statistical heterogeneity among studies was assessed using Cochran's Q test and the I^2 statistic. Values of I^2 greater than 75%, 50%, and 25% were interpreted as indicating high, moderate, and low heterogeneity, respectively. Subgroup analyses were conducted to explore potential sources of heterogeneity. However, these analyses were restricted to variables with sufficient and comparable data across a minimum of two studies. Variables that were inconsistently reported across the included studies were not considered suitable for subgroup meta-analysis. Accordingly, only animal species and provinces were eligible for subgroup meta-analysis.

Data on potential risk factors were independently extracted by two reviewers. Only variables meeting the criteria of adequate and comparable data across a minimum of two studies were included in the quantitative synthesis. Based on these criteria, only sex and age were included in the meta-analysis of risk factors. Pooled odds ratios (OR) with 95% CI were calculated using a random-effects model. Statistical heterogeneity was assessed using the I^2 statistic, and potential publication bias was evaluated using Egger's test. The distribution of studies across provinces in Indonesia is visualized using R 4.3.1 software, with base map layers obtained from OpenStreetMap.

Meta-regression and cumulative analysis

Meta-regression analysis was conducted to explore potential sources of heterogeneity among the included studies. However, given the relatively limited number of eligible studies, the selection of moderator variables was restricted to reduce the risk of model overfitting and unstable estimates. Methodological guidelines in meta-analysis recommend that meta-regression should generally be performed only when a sufficient number of studies are available, commonly applying a rule of thumb of approximately ten studies per covariate to avoid model overfitting and unstable estimates (Deeks et al., 2024). In the present study, several potentially relevant moderators, such as host species, diagnostic method, production system, and geographic location were unevenly distributed across the included studies, with some categories represented by only one or two studies. Such sparse data may produce unreliable parameter estimates and low statistical power. Therefore, meta-regression was restricted to publication year as a continuous moderator to evaluate potential temporal trends in reported prevalence. Other variables were explored descriptively or through subgroup analyses where possible. However, additional epidemiological variables such as management practices, seasonal factors, housing systems and other variables could not be quantitatively analyzed because these data were not consistently reported across the primary studies. A significant association between the variables and the pooled prevalence in meta-regression model was considered when the statistical significance was set at $p < 0.05$ (Or et al., 2024).

Risk of publication bias

Publication bias was assessed using the Egger's test and presented with a funnel plot. The presence of bias was indicated if a p-value in Egger's test was less than 0.1 (Egger et al., 1997). To address funnel plot asymmetry, the trim-and-fill method was employed to account for potentially missing studies and adjust the pooled prevalence estimates. In addition, a leave-one-out sensitivity analysis was conducted to evaluate the sensitivity and robustness of the meta-analytic findings. This approach entailed the sequential exclusion of individual studies to determine their influence on the overall effect estimates.

Quality assessment of individual studies

The quality of each study was assessed using a list of questions based on Ding et al. (2017), with slight modifications. The risk of bias was assessed by responding to and scoring the following questions: (1) Is the objective clearly stated and described? (2) Are the study period and settings clearly stated? (3) Is the sampling method specifically described? (4) Is the diagnostic method well defined? (5) Is the research outcome presented clearly? The answers were yes, unsure, or no, and the scoring was 2 (representing a low risk of bias), 1 (representing some concern), and 0 (representing a high risk of bias), respectively. The score range of each study was 0–10. Overall scores were used to categorize the results into three quality levels: high (≥ 7), medium (4–6), and low (≤ 3). The assessment of risk of bias is visually presented using a summary plot, which was generated via the Robvis website to improve visualization (McGuinness & Higgins, 2021).

RESULTS

Pooled Estimated Prevalence and Heterogeneity Assessment

Following the screening of inclusion and exclusion criteria, a total of 12 studies were included in the analysis. The screening process is shown in Figure 1, and the distribution of included studies is presented in Figure 2. The characteristics of the included studies investigating *Eimeria* infection in small ruminants in

Indonesia are presented in Table 1. The systematic review and meta-analysis, utilizing a random-effects model due to observed data characteristics, yielded an overall pooled prevalence estimate of 48.99% (95% CI: 26.23%–72.17%) (Figure 3). The analysis revealed substantial heterogeneity among the studies, as evidenced by a highly significant Q-statistic ($\chi^2 = 388.32$, $p < 0.01$) and a high I^2 of 97%. This extreme level of heterogeneity indicates that the vast majority of the observed variation in prevalence is attributable to true differences in the effect size across studies rather than sampling error. The resulting Prediction Interval (PI) was exceptionally wide, ranging from 1.70% to 98.15%, underscoring the considerable expected variability in prevalence across diverse settings.

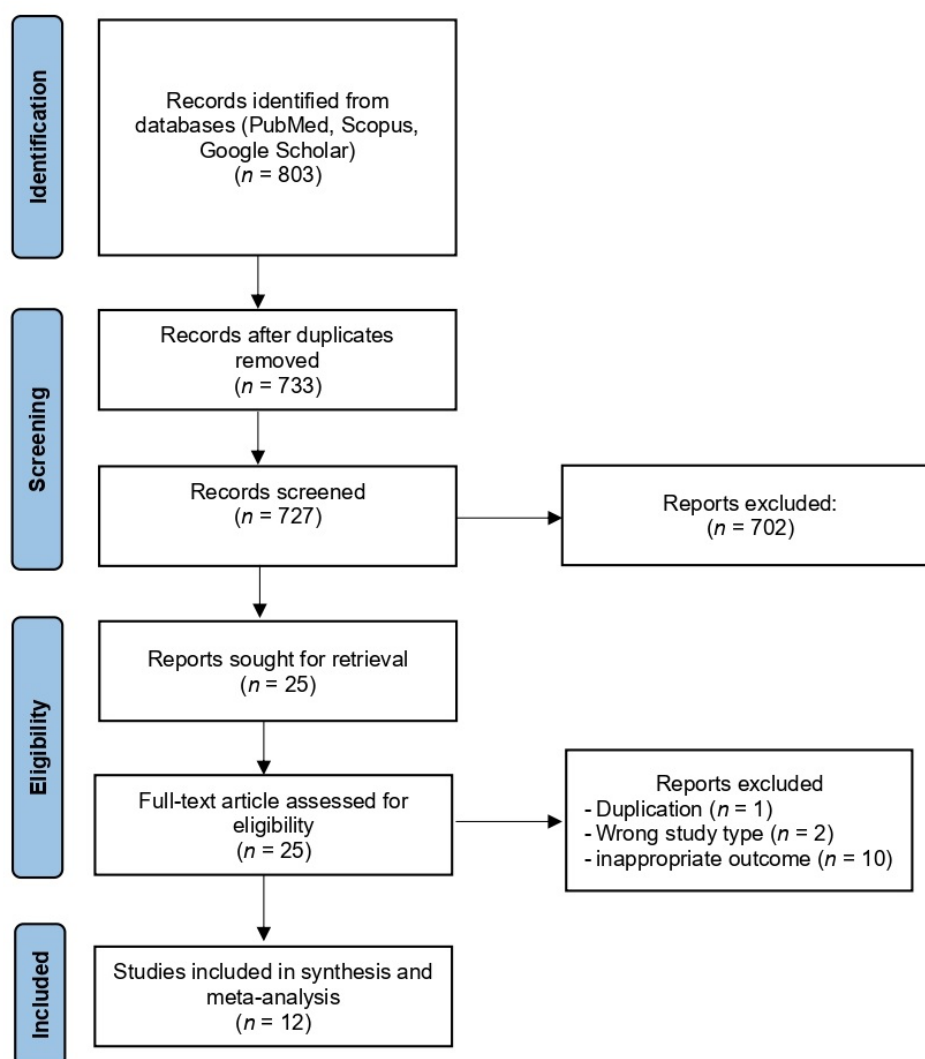


Figure 1 A flow diagram illustrates the screening process for included and excluded studies in this study.

Table 1 Characteristics of the included studies investigating *Eimeria* infection in small ruminants in Indonesia.

No	Author (Year)	Sampling period	Species	Animal	N	Case	Method	Gene	Province
1	Pertiwi et al., 2023	–	<i>Eimeria</i> spp.	Goat	100	70	DS + FT	-	Lampung
2	Dewi et al., 2025	–	<i>Eimeria</i> spp.	Goat	289	268	SSF + McM	-	Java
	Dewi et al., 2025	–	<i>Eimeria</i> spp.	Goat	15	15	SSF + McM	-	Banten
	Dewi et al., 2025	–	<i>Eimeria</i> spp.	Goat	38	37	SSF + McM	-	West Java
	Dewi et al., 2025	–	<i>Eimeria</i> spp.	Goat	187	170	SSF + McM	-	Central Java
	Dewi et al., 2025	–	<i>Eimeria</i> spp.	Goat	19	17	SSF + McM	-	Yogyakarta
	Dewi et al., 2025	–	<i>Eimeria</i> spp.	Goat	30	29	SSF + McM	-	East Java
	Dewi et al., 2025	–	<i>Eimeria christenseni</i>	Goat	18	18	PCR	18S rRNA	Java
	Dewi et al., 2025	–	<i>Eimeria arloingi</i>	Goat	18	18	PCR	18S rRNA	Java
3	Purwaningsih et al., 2024	January–March 2021	<i>Eimeria hirci</i>	Goat	36	7	FT (Whitlock)	-	West Papua
	Purwaningsih et al., 2024	January–March 2021	<i>Eimeria parva</i>	Goat	36	11	FT (Whitlock)	-	West Papua
	Purwaningsih et al., 2024	January–March 2021	<i>Eimeria christenseni</i>	Goat	36	30	FT (Whitlock)	-	West Papua
	Purwaningsih et al., 2024	January–March 2021	<i>Eimeria arloingi</i>	Goat	36	34	FT (Whitlock)	-	West Papua
	Purwaningsih et al., 2024	January–March 2021	<i>Eimeria alijevi</i>	Goat	36	4	FT (Whitlock)	-	West Papua
	Purwaningsih et al., 2024	January–March 2021	<i>Eimeria</i> spp.	Goat	207	187	FT (Whitlock)	-	West Papua
4	Awaludin et al., 2021	January–March 2021	<i>Eimeria ovinoidalis</i>	Sheep	104	17	FLOTAC	-	Yogyakarta
	Awaludin et al., 2021	January–March 2021	<i>Eimeria intricata</i>	Sheep	104	10	FLOTAC	-	East Java
5	Awaludin et al., 2021	October–December 2020	<i>Eimeria</i> spp.	Sheep	50	4	FT	-	East Java
6	Pramita et al., 2024	October–December 2023	<i>Eimeria</i> spp.	Goat	100	79	FT + McM	-	Bali
7	Abdillah et al., 2021	February–March 2021	<i>Eimeria</i> spp.	Goat	100	62	FT + McM	-	East Java
8	Afrian et al., 2025	–	<i>Eimeria</i> spp.	Goat	91	11	DS + Sed + FT	-	Gorontalo
9	Purwono et al., 2025	October–December 2024	<i>Eimeria</i> spp.	Sheep	50	5	FT	-	Central Java
10	Nanditya et al., 2023	March–May 2023	<i>Eimeria</i> spp.	Goat	55	19	FLOTAC	-	Yogyakarta
11	Nurdianti et al., 2023	–	<i>Eimeria</i> spp.	Sheep	62	20	FT	-	East Java
12	Efendi et al., 2019	April–July 2019	<i>Eimeria</i> spp.	Goat	100	80	SM + Sed + FF	-	East Java

DS = direct smear; FT = flotation technique; Sed = sedimentation; SSF = saturated sugar flotation; McM = McMaster method; FF = Fulleborn flotation; SM = simple method; PCR = polymerase chain reaction.

N = total number of examined animals.

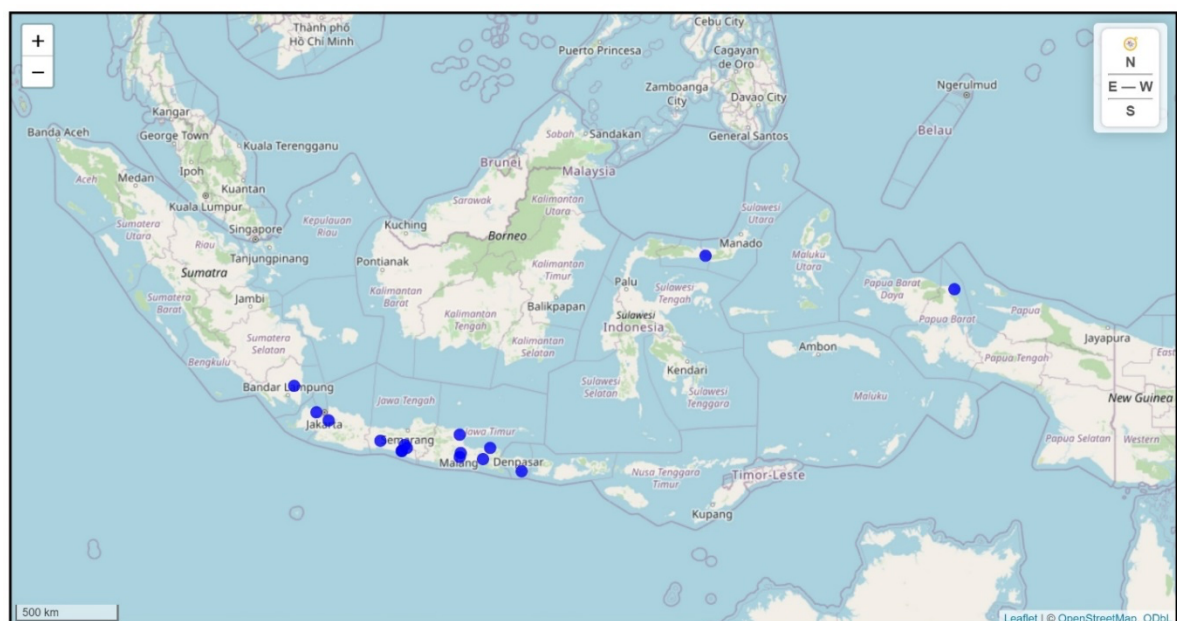


Figure 2 Geographic distribution of the eligible studies.

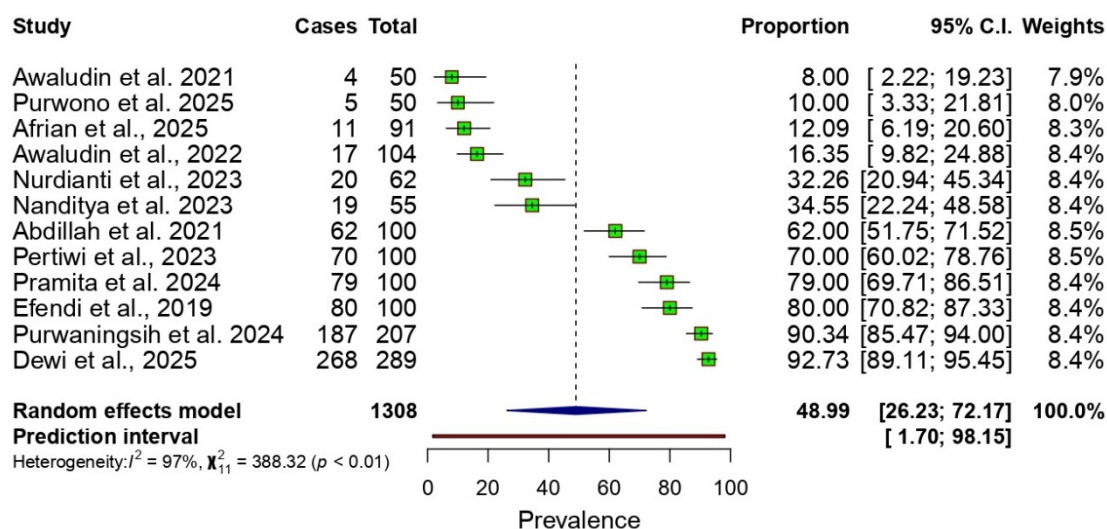


Figure 3 Forest plot of the pooled prevalence estimates of coccidiosis in small ruminants in Indonesia.

Subgroup Meta-analysis

To investigate potential sources of heterogeneity, subgroup analyses were conducted based on animal species and provinces. The analysis stratified by animal species revealed a statistically significant difference in pooled prevalence ($\chi^2 = 14.31$, $p < 0.01$) (Figure 4). The pooled prevalence in the goat subgroup was substantially higher at 68.68% (95% CI: 43.97%–85.97%), while the sheep subgroup showed a significantly lower prevalence of 15.84% (95% CI: 8.16%–28.50%). In addition, high heterogeneity persisted within both the goat ($I^2 = 97\%$) and sheep ($I^2 = 78\%$) subgroups. The subgroup analysis based on province (Yogyakarta, Central Java, and East Java) showed no statistically significant

difference in the pooled prevalence across regions ($\chi^2 = 2.11$, $df = 2$, $p = 0.35$) (Figure 5). Despite the absence of statistical significance, regional estimates varied, with pooled prevalence reported in East Java (57.95%; 95% CI: 18.61–89.26), Central Java (51.75%; 95% CI: 1.29–98.88), and Yogyakarta (24.21%; 95% CI: 10.77–45.83).

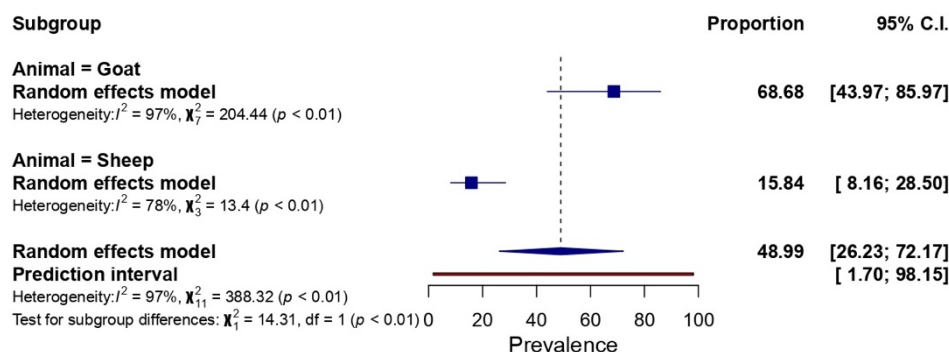


Figure 4 Subgroup forest plot based on animal subgroup analysis for coccidiosis in small ruminants in Indonesia.

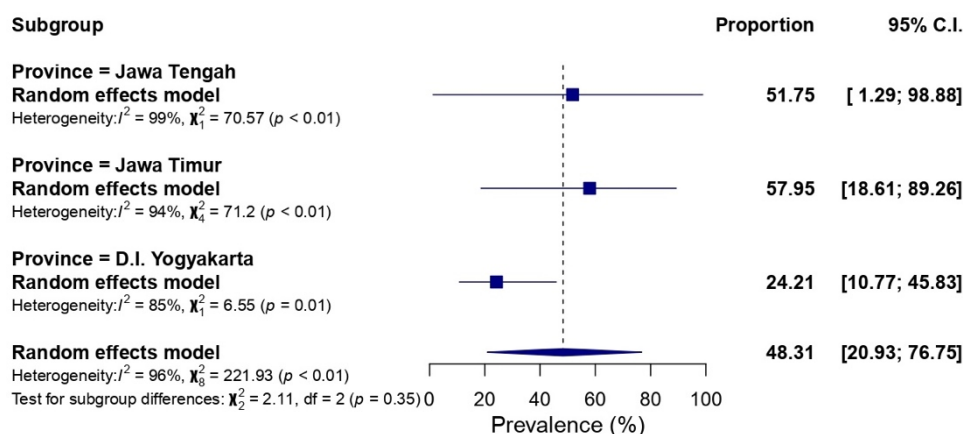


Figure 5 Forest plot of the province subgroup analysis of coccidiosis in small ruminants in Indonesia.

Risk factor analysis

The assessment of the included studies revealed that only a limited number of studies provided sufficient data for quantitative synthesis. Among the reported variables, only sex and age fulfilled the predefined inclusion criteria for meta-analysis. The pooled analysis showed no statistically significant association between sex and the occurrence of coccidiosis in small ruminants. Male animals had an OR of 0.99 (95% CI: 0.47–2.07; $p = 0.95$) compared with female animals. Heterogeneity among the included studies was negligible ($I^2 = 0\%$), indicating negligible heterogeneity across studies.

For age, animals aged ≤ 12 months had an OR of 2.77 (95% CI: 0.91–8.42) relative to animals aged > 12 months. However, this association did not reach

statistical significance ($p = 0.06$). The heterogeneity for this analysis was low ($I^2 = 9.8\%$), suggesting relatively consistent results among the included studies. Publication bias was assessed using Egger's test. No evidence of small-study effects was detected for the sex variable ($p = 0.63$). For age, Egger's test indicated borderline asymmetry ($p = 0.09$). Detailed results of the risk factor meta-analysis are presented in [Table 2](#).

Table 2 Summary of meta-analysis results for risk factors associated with coccidiosis prevalence in small ruminants in Indonesia.

Factors	k	n	OR (95% CI)	I^2 (%)	P value	Egger's test
Sex						
Female	Ref.					
Male	4	696	0.99 (0.47 to 2.07)	0	0.95	0.63
Age						
>12 months (adult)	Ref.					
≤12 months	4	695	2.77 (0.91 to 8.42)	9.8	0.06	0.09

k: number of studies, n: total sample size, Ref.: reference category, OR: Odds Ratio

Meta-regression analysis

Meta-regression analysis was performed to explore potential sources of heterogeneity among the included studies. However, the relatively small number of eligible studies limited the applicability of this approach. Several potential moderators, including host species, diagnostic methods, and geographic location (province), showed an uneven distribution across categories, with some levels represented by only one or two studies. Such sparse data may result in unstable parameter estimates and low statistical power in the meta-regression model. Therefore, meta-regression was restricted to publication year as a continuous variable to evaluate potential temporal trends in the reported prevalence. Other variables with limited or uneven data, such as host species and diagnostic methods, were further explored using subgroup analysis to allow descriptive comparisons while avoiding unreliable model estimates. Additional epidemiological variables could not be analyzed quantitatively because these factors were not consistently reported across the included studies.

A meta-regression was performed using the Year of study publication as a covariate in a mixed-effects model (REML) to assess a potential temporal trend. The results indicated no significant change in the logit event rate of prevalence over the study period, as confirmed by the non-significant Test of Moderators ($p = 0.99$) ([Figure 6](#)). The coefficient for Year was negligible (0.0056), with a wide confidence interval spanning zero (95% CI: -0.5738 to 0.5849). Most of the overall heterogeneity remained unexplained by the Year covariate, with residual heterogeneity still high ($I^2 = 97.87\%$). This suggests that temporal factors, as measured by publication year, were not a significant driver of the observed variation in prevalence.

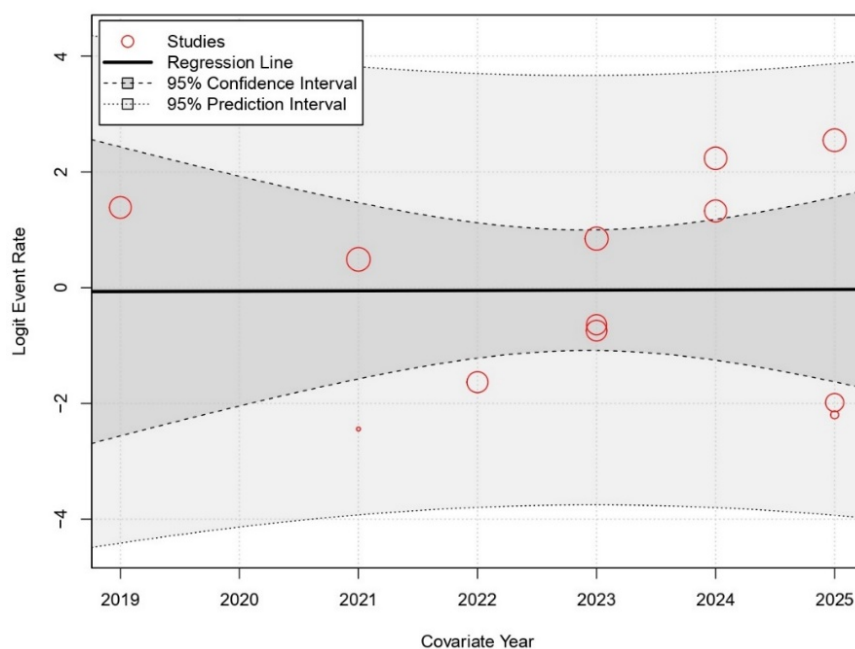


Figure 6 The meta-regression analysis revealed no statistically significant temporal trend in the prevalence of coccidiosis in small ruminants in Indonesia.

Cumulative and Sensitivity Analysis

The cumulative meta-analysis illustrated how the overall estimate evolved with the sequential addition of studies by publication year. The initial accumulated estimate was notably high (70.00% for the first study added), but as subsequent data were integrated, the pooled estimate stabilized, hovering around the 45%–48.99% range. This stabilization provides confidence that the overall conclusion has converged. Furthermore, the leave-one-out sensitivity analysis confirmed the robustness of the primary result. The omission of any single study resulted in only a slight variation in the pooled prevalence, which ranged from 43.16% (95% CI: 22.48%–66.54%) to 54.15% (95% CI: 30.56%–76.01%). This limited range of variation suggests that the overall estimate is reliable and not disproportionately influenced by any single influential study.

Risk of Publication Bias

The assessment of publication bias provided mixed evidence. Egger Regression Test yielded a significant result ($t = -2.74$, $p\text{-value} = 0.02$), suggesting significant asymmetry in the funnel plot, potentially indicating the presence of small study effects. Funnel plots illustrating the assessment of publication bias across all selected studies are shown in Figure 7. To account for the observed asymmetry, the trim and fill method was applied. This analysis identified and imputed three missing studies on the left side of the funnel plot, which typically corresponds to small studies with lower effect sizes. After this adjustment, the corrected pooled prevalence estimated significantly increased to 66.90% (95% CI: 39.75%–86.10%). This upward shift suggests that if publication bias favoring larger effect sizes in smaller studies is present, the true underlying prevalence may be considerably higher than the initial 48.99% estimate.

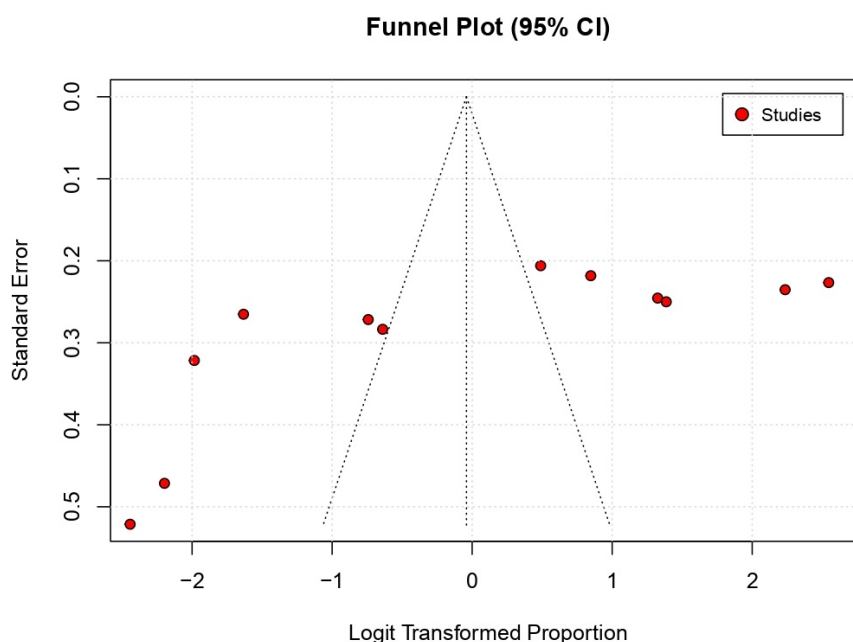


Figure 7 Funnel plots illustrating the assessment of publication bias across all selected studies.

Risk of bias assessment

The Risk of Bias (RoB) assessment was performed to summarize the distribution of study quality across the included literature. The mean RoB score was 8.42 ± 1.62 , indicating that the overall methodological quality of the studies tended to fall within an acceptable range with relatively limited variability. The median score of 8.5 further supports a relatively symmetrical distribution of study quality, despite the presence of a lower outlier score of 5. The observed range of 5 to 10 reflects a moderate spread in the level of risk of bias among studies. Additionally, the interquartile range, with $Q1 = 8.0$ and $Q3 = 10.0$, suggests that half of the included studies clustered within a narrow and higher-quality interval. The risk of bias assessment of the included studies is presented in [Figure 8](#).

DISCUSSION

This study estimated the pooled prevalence of *Eimeria* spp. infections in small ruminants in Indonesia at 48.99% (95% CI: 26.23–72.17%). This finding indicates that coccidiosis remains prevalent in some regions of small ruminant production systems in Indonesia. Comparable prevalence levels have been reported globally, although substantial regional variation exists. A recent global meta-analysis reported a prevalence of 62.9% in goats, ranging from 52.0% in Asia to 92.2% in North America ([Ali et al., 2024](#)). Epidemiological studies have documented prevalence estimates of 56.9% in sheep in Ethiopia ([Terfa et al., 2023](#)), 60% in goats and 57.7% in sheep in Egypt ([Mohamaden et al., 2018](#)), and up to 72.2% in sheep in South India ([Sharma et al., 2023](#)). In China, prevalence below 40% has been reported in southwestern and central regions, whereas eastern areas showed higher values of approximately 43.24% ([Liu et al., 2024](#)). In Southeast Asia, prevalence in small ruminants is around 50% in northern Thailand ([Wuthijaree et al., 2022](#)) and reaches up to 92.7% in Java, Indonesia ([Dewi et al., 2024](#)).

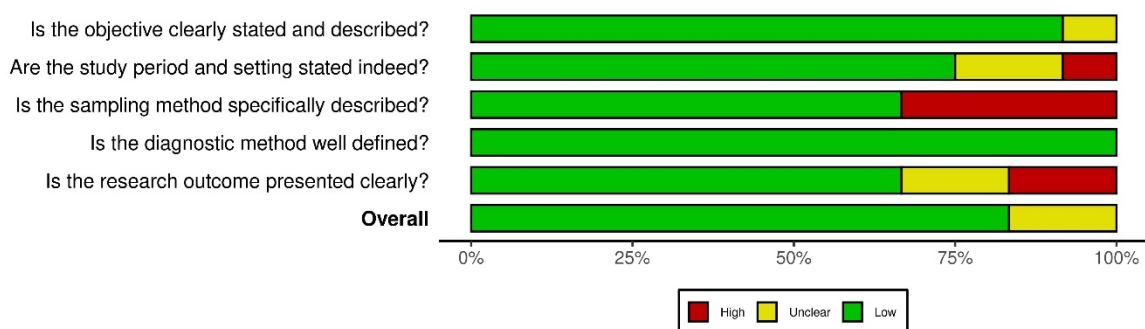
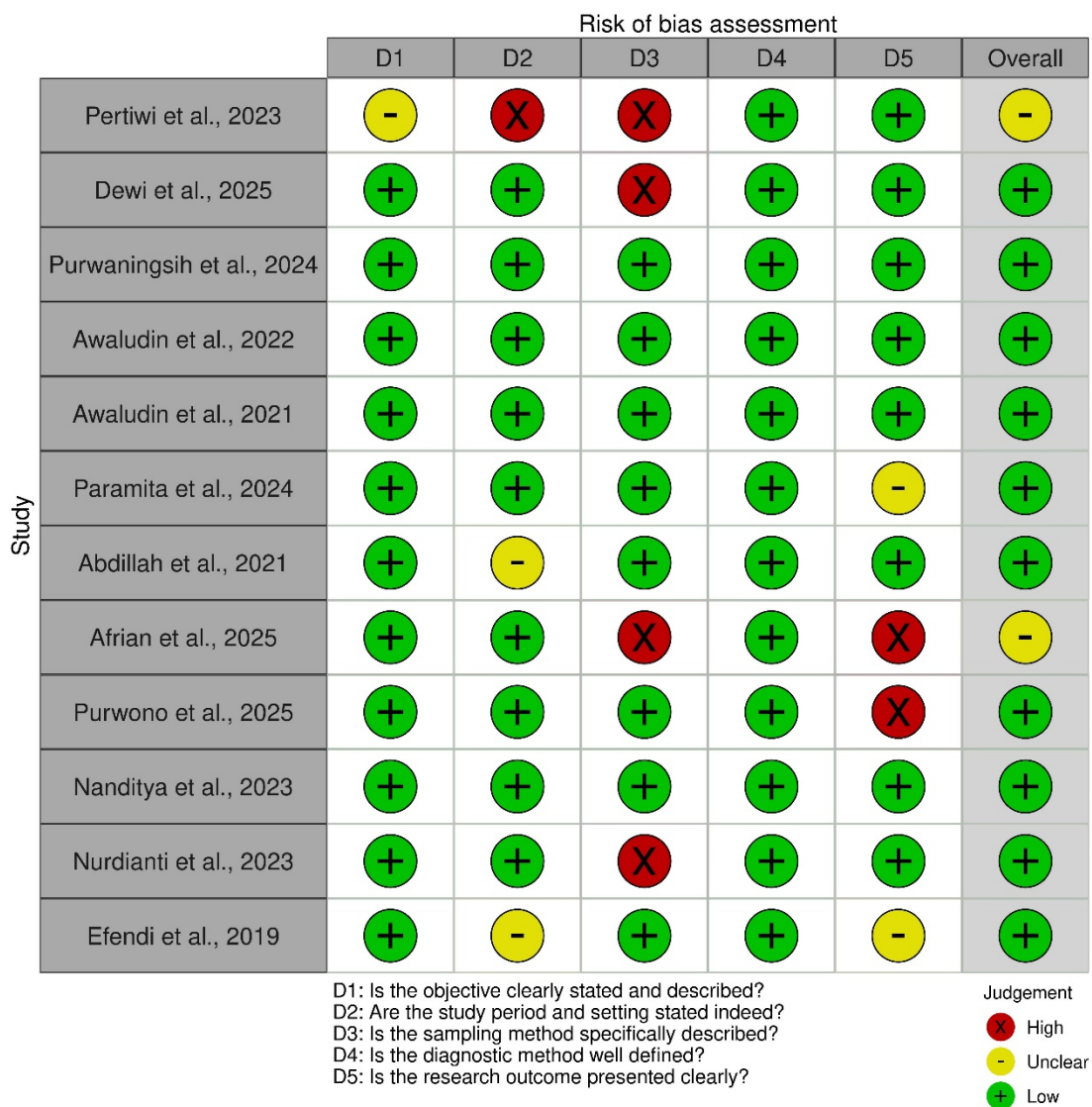


Figure 8 Risk of bias assessment of the included studies.

The high heterogeneity observed in this meta-analysis ($I^2 = 97\%$) indicates considerable variability among the included studies. Several methodological and epidemiological factors may contribute to this variation. To further investigate potential sources of heterogeneity, subgroup analyses and risk factor assessments were performed based on the variables available in the extracted data.

Subgroup analysis based on animal species revealed a significant difference in infection prevalence between goats and sheep ($p < 0.01$), with a higher pooled prevalence observed in goats (68.68%; 95% CI: 43.97–85.97%) compared to sheep (15.84%; 95% CI: 8.16–28.50%). Infection with *Eimeria* in sheep and goats exhibits several notable differences in terms of the parasite species involved, their pathogenicity, and the epidemiological patterns observed in each host. In sheep, the most frequently reported species include *E. ahsata*, *E. ovinoidalis*, *E. intricata*, *E. faurei*, and *E. crandallis*, with *E. ahsata* and *E. ovinoidalis* commonly recognized as the predominant and most pathogenic species affecting sheep (Vasilková et al., 2004; Hassanen et al., 2020; Liu et al., 2024). In addition, goats are more commonly infected by *E. arloingi*, *E. ninakohlyakimovae*, *E. hirci*, and *E. christensenii*, among which *E. arloingi* and *E. ninakohlyakimovae* are considered highly pathogenic and are frequently associated with more severe intestinal lesions in goats (Bakunzi et al., 2010; Khodakaram-Tafti et al., 2013; Hassanen et al., 2020; Liu et al., 2024). Cross-infection between sheep and goats is rarely observed, as *Eimeria* species typically exhibit strict host specificity (Bakunzi et al., 2010; Das et al., 2025). Epidemiological studies have further indicated that both the prevalence and intensity of infection are often measured as oocysts per gram of feces (OPG) tend to be higher in goats than in sheep, particularly among young animals (Vasilková et al., 2004). Despite differences in prevalence and pathogenic species composition, clinical coccidiosis in both hosts may produce comparable histopathological intestinal lesions (Vasilková et al., 2004; Khodakaram-Tafti and Mansourian, 2008; Liu et al., 2024).

Geographical subgroup analysis indicated no statistically significant variation in prevalence among provinces ($p = 0.35$), suggesting relatively similar infection pressure across the studied regions. This pattern may be partly explained by the relatively uniform tropical climatic conditions across much of Indonesia, which provide favorable environmental conditions for the sporulation and survival of *Eimeria* oocysts. Experimental studies have shown that temperature plays a critical role in oocyst sporulation, with higher temperatures (approximately 30–35 °C) substantially accelerating the sporulation process and reducing the time required for oocysts to become infective (Boyko et al., 2021). In addition, the presence of organic matter in water can support the environmental persistence of *Eimeria* oocysts, as sporulated oocysts have been shown to remain viable for up to 12 months under environmental conditions in a tropical climate, indicating that contaminated water may serve as an important reservoir facilitating transmission (Cruvinel et al., 2024). These conditions are commonly found in tropical production systems and may support continuous transmission cycles. Furthermore, epidemiological studies in Indonesia have suggested that farm management practices, environmental sanitation, and housing conditions may influence the level of environmental contamination with *Eimeria* oocysts, although similar husbandry systems across regions may result in comparable infection pressure (Ekawasti et al., 2021; Purwaningsih et al., 2024).

The meta-analysis of risk factors found no statistically significant effect of age on coccidiosis in small ruminants (≤ 12 months vs. adults: OR = 2.77; 95% CI: 0.91–8.42; $p = 0.06$), with low between-study heterogeneity ($I^2 = 9.8\%$). Similarly, sex was not associated with disease occurrence (males: OR = 0.99; 95% CI: 0.47–2.07; $p = 0.95$; $I^2 = 0\%$). However, several studies have reported that young animals (1–6 months) are more susceptible due to immature immunity, which gradually develops with repeated *Eimeria* exposure, leading to reduced oocyst shedding and milder clinical disease in older individuals (Chartier and Paraud, 2012; Khodakaram-Tafti and Hashemnia, 2017; Matos et al., 2018; Mohammed et al.,

2021). Evidence regarding sex-related susceptibility remains inconsistent. Some studies have reported higher prevalence in adult females, possibly associated with physiological stress during pregnancy and lactation, whereas others have found no significant differences (Mohamaden et al., 2018; Adeyemi et al., 2021; Paul et al., 2024). Environmental and management factors, including intensive rearing, poor hygiene, overcrowding, and seasonal conditions that favor oocyst sporulation, further increase infection risk (de Macedo et al., 2020; Purwaningsih et al., 2024; Liu et al., 2024; Hundal et al., 2025). Epidemiological analyses using OR and logistic regression have shown that large herd sizes and suboptimal husbandry practices are associated with a higher likelihood of infection (de Macedo et al., 2020; Purwaningsih et al., 2024). Subclinical infections are widespread and contribute to reduced growth and productivity, highlighting the need for targeted control measures, particularly in young animals and during periods of environmental or physiological stress (Chartier and Paraud, 2012; Khodakaram-Tafti and Hashemnia, 2017; Rabeea et al., 2025).

Temporal analyses further indicated that the overall prevalence estimate remained relatively stable throughout the study period. Meta-regression analysis showed no significant association between publication year and infection prevalence ($p = 0.99$), suggesting that the occurrence of *Eimeria* infections in small ruminants in Indonesia has not substantially changed over time. The regression model was described by the equation $\text{logit event rate} = -11.3182 + 0.0056 \times \text{year}$ (95% CI: -0.5738 to 0.5849), indicating the absence of a temporal trend. This observation was further supported by the cumulative meta-analysis, which demonstrated that after initial fluctuations, the pooled prevalence gradually stabilized at approximately 45–49%. Moreover, sensitivity analysis using the leave-one-out approach confirmed the robustness of the pooled estimate, with prevalence values ranging from 43.16% to 54.15% following the sequential exclusion of individual studies. These findings indicate that the estimated prevalence is consistent and robust, supporting the notion that coccidiosis remains endemic in small ruminant production systems in Indonesia.

This study has several limitations in understanding the epidemiology of *Eimeria* spp. infections in small ruminants in Indonesia. First, the number of eligible published studies remains limited and unevenly distributed across regions, reducing the representativeness of the available evidence. Second, most studies rely on morphological identification of *Eimeria* oocysts. Although this approach is suitable for routine surveillance, overlapping morphological characteristics among species increase the risk of misclassification and often restrict identification to the genus level, thereby limiting species-specific epidemiological interpretation (Chartier and Paraud, 2012; Nurdianti et al., 2023). In addition, microscopy-based diagnostic techniques, such as flotation and the McMaster method, are widely used in field studies but differ in sensitivity and detection limits. Flotation methods generally provide higher sensitivity, whereas the McMaster technique, although practical for quantifying oocysts per gram (OPG), may underestimate low-intensity infections (Barda et al., 2014). These methodological differences may contribute to variability in reported prevalence estimates. Finally, publication bias is indicated by the asymmetry of the funnel plots and the results of Egger's test, suggesting that smaller studies tend to report lower prevalence estimates. These bias warrants cautious interpretation of the findings and highlights the need for more robust and comprehensive epidemiological studies.

CONCLUSIONS

The results of this systematic review and meta-analysis show that coccidiosis caused by *Eimeria* spp. in small ruminants in Indonesia has a pooled prevalence of 48.99%, with considerable heterogeneity between studies. Goats exhibited a significantly higher prevalence of *Eimeria* spp. infection compared to

sheep. The differences between provinces are not significant, possibly due to uniform tropical climatic conditions that support oocyst sporulation. Additionally, the meta-analysis of risk factors indicated that neither age nor sex was significantly associated with the occurrence of coccidiosis in small ruminants. Meta-regression analysis showed no significant change in prevalence over time, indicating that *Eimeria* infection remains persistent. Although there are indications of publication bias that may affect the accuracy of the actual prevalence estimate, the results of the sensitivity analysis showed that the findings are quite stable and robust. Overall, coccidiosis remains an important problem for the health and productivity of small ruminants in Indonesia, requiring improved husbandry management, biosecurity, and the application of more accurate diagnostics.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest associated with this study. Artificial Intelligence (AI) tools (ChatGPT) were used for language editing and content structuring. The authors confirm that all outputs were critically reviewed and that they take full responsibility for the integrity and accuracy of the content.

AUTHOR CONTRIBUTIONS

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Morsid Andityas: Conceptualization (lead), Methodology (lead), Formal Analysis (lead), Data Curation (supporting), Visualization (lead), Validation (equal), Writing – Original Draft (lead), Writing – Review & Editing (lead), Supervision (lead).

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