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Prevalence of phenotypic drug resistance profiles and multi-drug-resistant *Pseudomonas* and *Acinetobacter species* recovered from clinical specimens in Ethiopia: a systematic review and meta-analysis

Mihret Tilahun[1*], Alemu Gedefie[1], Abdurahaman Seid[1], Habtu Debash[1] and Agumas Shibabaw[1]

Abstract

Background Antimicrobial-resistant *Pseudomonas* and *Acinetobacter* species are emerging as serious public health risks, both globally and in resource-limited countries such as Ethiopia. These microorganisms cause serious, life-threatening infections and are becoming increasingly resistant to commonly prescribed antibiotics. The high prevalence and resistance patterns of these bacteria need immediate action to inform treatment guidelines, increase infection control measure, and develop effective public health policies. This systematic review and meta-analysis aimed to assess the prevalence of phenotypic drug resistance profiles and multi-drug-resistant *Pseudomonas* and *Acinetobacter species* recovered from clinical specimens in Ethiopia.

Methods This systematic review and meta-analysis, which followed PRISMA principles, analyzed data from PubMed, Scopus, and Google Scholar to determine the prevalence and antibiotic resistance trends of *Pseudomonas* and *Acinetobacter* species in Ethiopia. Eligible studies were extracted by using Microsoft Excel and exported to STATA version 17 for analysis. The pooled prevalence was estimated using a random-effects model, and heterogeneity was examined using the I^2 statistic. Publication bias was investigated using funnel plot analysis and Egger's test, and sensitivity analysis was used to assess the impact of individual studies on the total pooled findings.

Result Of the 1,375 studies identified, 187 were eligible for qualitative analysis, leading to the inclusion of 65 studies in the meta-analysis. This analysis encompassed a total of 1,264 isolates, with 364 identified as *Pseudomonas* and *Acinetobacter* species. The systematic review revealed a pooled prevalence of 19.12% (95% CI: 14.86–23.38) for *Pseudomonas* species and 12.46% (95% CI: 5.82–19.10) for *Acinetobacter* species. The combined prevalence of both pathogens was 25.31 (95% CI: 18.61–32.00) with substantial heterogeneity ($I^2 = 93.6\%$, $p < 0.001$). across the studies. *Pseudomonas* exhibited high resistance rates to amoxicillin-clavulanic Acid (83.73%) and tetracycline (89.15%), while *Acinetobacter* showed 87.21% resistance to tetracycline and 79.72% to ceftriaxone. The overall pooled prevalence of MDR *Pseudomonas* species was 72.73% (95% CI: 67.02–78.44), and for *Acinetobacter* species, it reached 84.69% (95% CI: 78.78–90.59), respectively. Moreover, the pooled prevalence of MDR for both species isolated from clinical

*Correspondence:
Mihret Tilahun
tilahunmihret21@gmail.com

samples in Ethiopia was 74.79% (95% CI: 70.14–79.43), with significant heterogeneity ($I^2 = 99.7\%$, $p < 0.001$) across the studies.

Conclusion The pooled prevalence of *Pseudomonas* and *Acinetobacter* species and their antibiotic resistance were alarmingly high in clinical samples in Ethiopia. These findings highlight the crucial need for more antimicrobial surveillance, stronger stewardship programs, and targeted research to combat the growing threat of resistance. Strategic public health policies are required to decrease these pathogens.

Keywords *Acinetobacter*, *Pseudomonas*, Antimicrobial resistance, Ethiopia, Systematic review and meta-analysis

Introduction

The alarming rise of multidrug-resistant (MDR) bacteria, particularly *Pseudomonas aeruginosa* (*P. aeruginosa*) and *Acinetobacter baumannii (A. baumannii)*, is a serious and growing public health concern. These pathogens are known for causing severe infections in healthcare settings, particularly among susceptible groups such as immunocompromised patients and the elderly [1]. *P. aeruginosa* and *A. baumannii*, both non-fermenting Gram-negative bacteria from the ESKAPE (*E. faecium*, S. aureus, *K. pneumoniae*, *A. aumannii*, *P. aeruginosa*, and *Enterobacter* species) group, are classified as critical-priority pathogens by the WHO. This is due to their high intrinsic resistance, rapid acquisition of new resistance mechanisms, and significant participation in hospital-acquired infections, and contribution to global antimicrobial resistance [2].

Antibiotic resistance varies by region, influenced by prescribing practices, infection control measures, and socioeconomic status. Strong antibiotic stewardship in high-income countries has been successful in reducing the issue [3]. In contrast, low- and middle-income countries (LMICs), like Ethiopia, face escalating multidrug-resistant strains of *Pseudomonas* and *Acinetobacter* due to widespread overuse and misuse of antibiotics without proper medical oversight [4, 5]. The lack of robust healthcare infrastructure and limited access to essential medical services exacerbate this issue, leading to increased rates of healthcare-associated infections and treatment failures [6].

Other clinically relevant species like *P. putida*, *P. fluorescens*, *P. stutzeri*, *A. calcoaceticus*, *A. junii*, and *A. lwoffii* also cause hospital-acquired infections. These opportunistic pathogens show resistance to beta-lactams, carbapenems, and aminoglycosides, contributing to the challenge of managing multidrug-resistant infections in healthcare settings [7].

In Ethiopia, the prevalence of multidrug-resistant (MDR) Pseudomonas aeruginosa reported to 72.73%, while *A. baumannii* shows resistance rates exceeding 80% [8]. The rising prevalence of MDR Pseudomonas and Acinetobacter species in Ethiopia presents a multifaceted public health challenge. The high rates of antibiotic resistance complicate the management of infections, leading to increased morbidity, mortality, and healthcare costs [9].

P. aeruginosa and *A. baumannii* are highly multidrug-resistant pathogens. *Pseudomonas* often resists to beta-lactams, including carbapenems, primarily through the production of beta-lactamases. It also shows significant resistance to aminoglycosides and fluoroquinolones [10]. *A. baumannii* similarly demonstrates high resistance to carbapenems and aminoglycosides, due to efflux pump overexpression, porin channel loss, biofilm formation, and horizontal gene transfer of resistance determinants such as beta-lactamases. Additionally, the emergence of colistin resistance primarily linked to modifications of the lipopolysaccharide structure, gene-mediated alterations or adaptive resistance mechanisms further complicates treatment options [11].

In Ethiopia, the burden of healthcare-associated infections is compounded by limited diagnostic infrastructure, inappropriate antibiotic use, and inadequate infection prevention and control practices factors that collectively accelerate the transmission of multidrug-resistant (MDR) pathogens [12]. Among these, *Pseudomonas* and *Acinetobacter* species are of particular concern due to their high prevalence in healthcare settings and their exceptional capacity to develop resistance to multiple antimicrobial agents, posing significant challenges to clinical management and infection control [13].

This systematic review and meta-analysis intended to offer a complete picture of the prevalence and antimicrobial resistance profiles of *Pseudomonas* and *Acinetobacter* species in Ethiopia by pooling data from different studies across regions and demographics. The review defines the present resistance landscape and identifies new patterns that will help guide empirical treatment options. The findings provide useful insights for doctors, public health officials, and politicians, informing the creation of

targeted treatments such as antibiotic stewardship programs, increased infection prevention and control measures, and improved surveillance systems. Furthermore, the study emphasizes the critical need for coordinated action among healthcare professionals, researchers, and policymakers to address the escalating threat of antimicrobial resistance and ensure the efficacy of current and future treatment options.

Methodology

Design and protocol registration

This systematic review and meta-analysis was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA) 2020 guidelines [14]. The protocol for these reviews this review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) database with the registration identification number of CRD42024517783.

PROSPERO 2024 Available: from https://www.crd.york.ac.uk/PROSPERO/view/CRD42024517783.

Search strategies and selection of studies

A systematic literature search was conducted to gather studies on the prevalence and multidrug resistance of *Pseudomonas* and *Acinetobacter* species in Ethiopia. This search spanned electronic databases, including PubMed/Medline, Science Direct, EMBASE, Scopus, and Web of Sciences, as well as grey literature sources like Google Scholar and ResearchGate. Additionally, reference lists of included studies were reviewed for relevant works. Eligible studies published between January 2000 and April 30, 2024, were considered for inclusion. The searching strategy utilized Medical Subject Headings (MeSH) terms and combinations of keywords such as"p revalence","epidemiology","burden","incidence","*Pseudo monas*","*Acinetobacter*","antibiotic resistance","antibiotic susceptibility","multidrug resistance","children","Clini cal sample", and"Ethiopia", employing Boolean operators ("OR"and"AND") as necessary in advanced database searches.

Eligibility criteria

We developed a selection criteria checklist to identify eligible peer-reviewed articles on the prevalence of *Pseudomonas* and *Acinetobacter* species as well as their antibiotic resistance profiles in all clinical samples from Ethiopia. From January 2000 to April 2024, the inclusion criteria included laboratory-based observational studies (e.g., cross-sectional) with defined antimicrobial susceptibility tests that were published in English and available online. Exclusions included qualitative studies, reviews, letters to the editor, studies on environmental or animal samples ensures that the analysis remains focused on clinically relevant data, i.e., pathogens isolated from human specimens, and those lacking clear methods or outcomes of interest.

Data extraction

The data from eligible papers were extracted independently by three reviewers (MT, AGS, and HD) using Microsoft Excel. The data retrieved comprised the first author's name, publication year, setting, region, sample type, sample size, bacterial isolate type, number of isolates, and multidrug resistance status. EndNote 20 was used to condense searched results and delete duplicates. Four independent reviewers (MT, MA, AS, and AGS) identified articles from various sources, and duplicates were eliminated. Three reviewers (MT, HD, and AG) evaluated the titles and abstracts of all retrieved studies, with MT and AS double-checking them. Full texts of potentially eligible studies were thoroughly evaluated against the inclusion criteria by three reviewers (MT, AGS, and AG), with additional verification from two reviewers (HD and AS). Discrepancies during data extraction were resolved through discussion and consensus among the reviewers, with a third reviewer (MT, AS, or AG) consulted when agreement could not be reached.

Quality assessment

The quality of the articles was assessed by three authors (AS, MAB, and HD) using the full texts to determine compliance with the selection criteria. The Joanna Briggs Institute (JBI) quality assessment manual guided the evaluation of each study's methodological validity [15]. Using critical appraisal checklists, studies were rated, with scores of 50% to 75% deemed good quality and those above 75% classified as high quality. Consequently, articles with good and high quality were included in this systematic review and meta-analysis (Supplementary Table 11).

Outcome variables

The primary outcome variable for this study was the pooled prevalence of *Pseudomonas and Acinetobacter species* reported in diarrheal diseases and the second outcome was to determine the pooled prevalence of antimicrobial resistance profile and multidrug resistance profile of these species in Ethiopia.

Data processing and analysis

Data were analyzed using STATA version 14.0 statistical software. A random-effects model was employed to account for the anticipated heterogeneity across studies, as suggested by preliminary analyses of pooled prevalence and multidrug resistance (MDR) rates. To further explore potential sources of heterogeneity, subgroup analyses and meta-regression were performed. The Cochran's Q test and I^2 statistics quantified heterogeneity between studies, with a p-value of <0.05 indicating significant heterogeneity [16] and prevalence estimates were stabilized using the Freeman–Tukey double arcsine transformation prior to pooling. A DerSimonian–Laird random-effects model was applied for meta-analysis to account for high between-study heterogeneity [17]. Subgroup analysis and meta-regression were conducted to investigate potential sources of heterogeneity, considering factors such as patients'region, study location, study design, and sample size. Results were presented using tables and forest plots. Publication bias was evaluated by inspecting funnel plot symmetry and applying Egger's test statistics. The Trim-and-Fill method was utilized for asymmetrical funnel plots to account for missing studies and estimate adjusted effect sizes. Additionally, meta-regression was employed to further investigate the causes of heterogeneity.

Result

PRISMA flow diagram illustrating the process of selecting eligible studies for the systematic review and Selection and identification of studies

A total of 1,375 articles were retrieved from multiple. After removing 820 duplicate articles, 555 remained. From these, 368 papers were removed based on their title, abstract, and study objective reviews. Finally, 187 full-length publications were thoroughly evaluated against established eligibility criteria, resulting in the inclusion of 65 studies in the meta-analysis (Fig. 1).

Study characteristics

Table 1 summarizes the characteristics of the 65 articles used in final meta-analysis. These studies, conducted between 2000 and 2024 across various regions of Ethiopia, were used to estimate the pooled prevalence of *Pseudomonas* and *Acinetobacter species*. A total of 23,921 individuals have been included, with sample sizes ranging from 51 to 1,416. The studies were conducted in two city administrations and five national regional states in Ethiopia, with more than 95% using a cross-sectional design. Among the 1,628 reported bacterial isolates, 1,264 were Pseudomonas species and 364 were *Acinetobacter* species. The most pathogens were identified from individuals with ear infections (551 isolates), followed by hospitalized patients (214), pneumonia patients

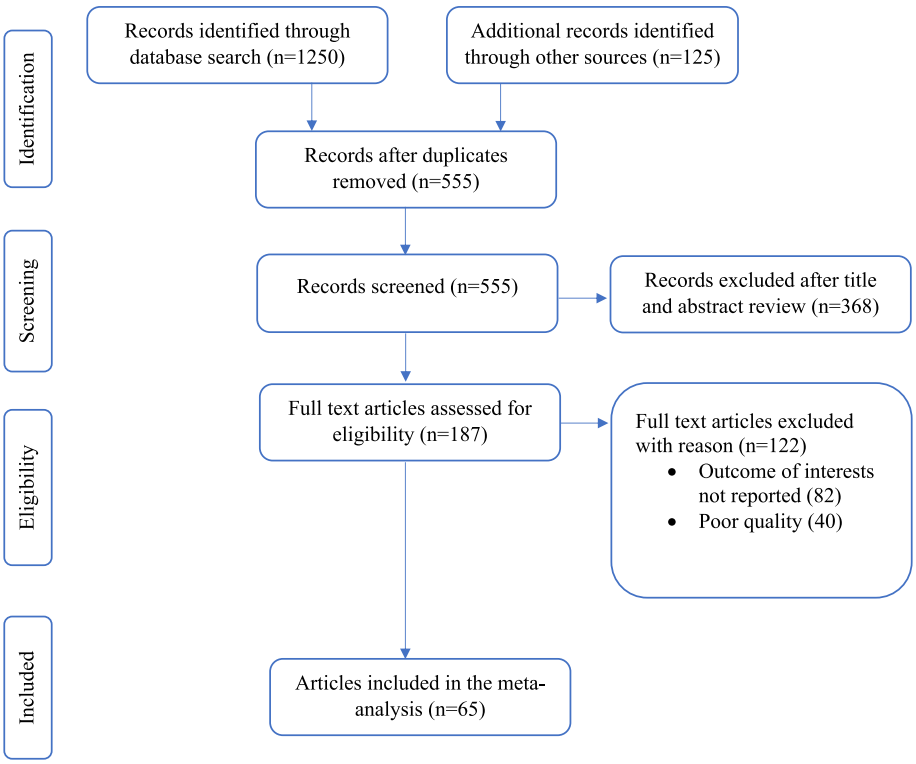

Fig. 1 PRISMA flow diagram illustrating the process of selecting eligible studies for the systematic review and meta-analysis

Table 1 Characteristics of studies

Author	Study area	Region	Publication year	Study population	Type of patients	Type of infections	Sample types (Culture specimens)	Sample size	Total pathogen isolated	Prevalence (%)	Pseudomonas Spp	Pseudomonas Spp		Acinetobacter spp	Acinetobacter spp		Total MDR
												MDR N	MDR %		MDR N	MDR %	
Abera *et al* [30]	Dessie	Amhara	2011	children and adult	ENT suspected patients	Ear infections	Ear discharge	897	148	16.5	148	100	67.56				67.56
Dereje et al. [31]	Addis Ababa	Central	2017	Age ≥ 10 years	Fistula patients	UTI	Clean catch mid-stream	210	4	1.9	4	3	75				75
Misha et al. [32]	Jimma	Oromia	2021	Age ≥ 18 years	Hospitalized patients	SSI	pus, pus aspirates, and wound swabs	251	8	3.2	8	7	87.5				87.5
Endaylalu et al. [33]	BahirDar	Amhara	2020	All age groups	ENT suspected patients	Ear infections	Ear discharge	236	54	22.9	54	29	53.7				53.7
Getaneh et al. [34]	Gondar	Amhara	2021	All age groups	ENT suspected patients	Ear infections	Ear discharge	369	35	9.5	24	18	75	11	8	72.7	74.3
Gorems et al. [35]	Jimma	Oromia	2018	All age groups	ENT suspected patients	Ear infections	Ear discharge	173	19	11	19	15	78.9				78.9
Hailu et al. [36]	BahrDar	Amhara	2016	All age groups	ENT suspected patients	Ear infections	Ear discharge	368	88	23.9	88	75	85.2			75.2	75.2
Gashaw et al. [37]	Jimma	Oromia	2018	All age groups	Hospitalized patients	HAI	clinical sample	240	11	4.6	9	7	7.8	2	1	50	72.7
Chernet et al. [38]	Adama	Oromia	2020	All age groups	Hospitalized patients	HAI	clinical sample	300	4	1.33	4						
Molla et al. [39]	Gondar	Amhara	2019	All age groups	ENT suspected patients	Ear infections	Ear discharge	62	2	3.2	2	2	100				
Muluye et al. [40]	Gondar	Amhara	2013	All age groups	ENT suspected patients	Ear infections	Ear discharge	228	33	14.5	18	15	83.3	15	12	80	81.8
Muleta [41]	Jimma	Oromia	2004	Children < 15 years	ENT suspected patients	Ear infections	Ear discharge	170	18	10.6	18						
Hailegiyorgis et al. [42]	Addis Ababa	Addis Ababa	2018	Children < 15 years	ENT suspected patients	Ear infections	Ear discharge	210	19	9.05	11						
Tolera et al. [43]	Harar	Harari	2018	All age groups	Hospitalized patients	HAI	Clinical sample	394	6	1.52	6	4	66.7				66.7
Seid et al. [44]	Dessie	Amhara	2013	All age groups	ENT suspected patients	Ear infections	Ear discharge	191	30	15.7	30	4	66.7				66.7

Table 1 (continued)

Author	Study area	Region	Publication year	Study population	Type of patients	Type of infections	Sample types (Culture specimens)	Sample size	Total pathogen isolated	Prevalence (%)	Pseudomonas Spp	Pseudomonas Spp		Acinetobacter spp	Acinetobacter spp		Total MDR
												MDR N	MDR %		MDR N	MDR %	
Tadesse et al. [45]	Hawassa	Sidama	2019	Children < 15 years	ENT suspected patients	Ear infections	Ear discharge	152	8	5.3	6	5	83.3	2	2	100	87.5
Girma et al. [46]	Pawi	Amhara	2022	All age groups	Patients Suspected of UTI	UTI	Clean catch mid-stream urine	141	8	5.7	8	6	75				75
Negash [47]	Addis Ababa	Addis Ababa	2019	Children < 15 years	Patients Suspected of Pneumonia	Pneumonia	Sputum	549	4	0.73	3	2	66.7	1	1	100	75
Nurahmed et al. [48]	Addis Ababa	Addis Ababa	2020	All age groups	Patients Suspected of Pneumonia	Pneumonia	Sputum	240	8	3.33	7	5	71.4	1	1	100	75
Hailu et al. [49]	BahrDar	Amhara	2016	All age groups		Wound infections	pus, pus aspirates, and wound swabs	380	27	7.1	27	15	55.5				55.5
Regassa et al. [50]	Arba Minch	Amhara	2014	Adult patients	Patients Suspected of Pneumonia	Pneumonia	Sputum	170	12	7.1	12	15	55.5				55.5
Atlaw et al. [51]	Addis Ababa	Addis Ababa		All age groups		Diabetic patients	pus, pus aspirates, and wound swabs	130	36	27.7	24	22	91.6	12	12	100	94.4
Sisay et al. [52]	Dessie	Amhara	2024	All age groups	Hospitalized patients	HAI	clinical samples:	384	16	4.2	15	10	66.7	1	11	100	68.8
Gebre et al. [53]	Hawassa	Sidama	2021	All age groups	Patients Suspected of Pneumonia	Pneumonia	Sputum	406	44	10.8	25	2	16	19	2	10.5	9.1
Temesgen et al. [54]	BahrDar	Amhara	2019	Adult patients	Patients Suspected of Pneumonia	Pneumonia	Sputum	414	19	4.6	19	8	42.1				42.1
Tilahun et al. [55]	Dessie	Amhara	2023	All age groups	Patients Suspected of Pneumonia	Pneumonia	Sputum	378	36	9.5	34	29	85.3	2	2	100	86.1

Table 1 (continued)

Author	Study area	Region	Publication year	Study population	Type of patients	Type of infections	Sample types (Culture specimens)	Sample size	Total pathogen isolated	Prevalence (%)	Pseudomonas Spp	Pseudomonas Spp		Acinetobacter spp	Acinetobacter spp		Total MDR
												MDR N	MDR %		MDR N	MDR %	
Dessie et al. [56]	Dessie	Amhara	2021	all patients aged ≥ 5 years	Patients Suspected of Pneumonia	Pneumonia	Sputum	406	25	6.2	22	10	45.5	3	3	100	52
Haile et al. [57]	Markos	Amhara	2021	All age groups	ENT suspected patients	Ear infections	Ear discharge	207	1	0.5	22	10	45.5	3	3	100	52
Moges et al. [58]	Amhara	Amhara	2021	All age groups	Hospitalized patients	HAI	clinical samples:	833	6	0.7	6	6	100				100
Assefa et al. [59]	Gondar	Amhara	2022	Adult patients	Patients Suspected of Pneumonia	Pneumonia	sputum	312	5	1.6	5	5	100				100
Asmare et al. [60]	Bahirdar	Amhara	2024	All age groups	Patients Suspected of UTI	UTI	Clean catch mid-stream	363	8	2.2	6	8	100	2	2	100	100
Alebel et al. [61]	BahrDar	Amhara	2021	Adult patients	Hospitalized patients	HAI	Clinical samples	270	24	8.9	11	11	100	13	13	100	100
Henok et al. [62]	Arbamich	SNNR	2023	Children < 15 years	ENT suspected patients	Ear infections	Ear discharge	312	17	5.4	13	11	84.6	4	3	75	82.35
Alelign et al. [63]	Arbamich	SNNR	2023	All age groups		peritoneal	ascitic fluid	147	4	2.7	13	2	50				50
Tilahun et al. [9]	Dessie	Amhara	2022	All age groups	Hospitalized patients	HAI	clinical samples:	423	75	17.7	46	39	84.8	29	26	89.7	86.7
Tilahun et al. [64]	Dessie	Amhara	2022	All age groups	Hospitalized patients	SSI	Clinical samples	384	34	8.9	31	21	67.7	3	1	33.3	64.7
Regasa, et al. [65]	Jimma	Oromia	2015	Adult patients	Patients Suspected of Pneumonia	Pneumonia	Sputum and Blood	133	10	7.5	10	2	20				20
Adugna, et al. [66]	Dessie	Amhara	2021	Adult patients	Patients Suspected of UTI	UTI	Clean catch mid-stream	422	4	0.94	3						
Adhanom et al. [67]	Mekele	Tigray	2019	Age ≥ 18 years	Patients Suspected of Pneumonia	Pneumonia	SPutum	252	4	1.6	46	1	25				

Table 1 (continued)

Author	Study area	Region	Publication year	Study population	Type of patients	Type of infections	Sample types (Culture specimens)	Sample size	Total pathogen isolated	Prevalence (%)	Pseudomonas Spp	Pseudomonas Spp		Acinetobacter spp	Acinetobacter spp		Total MDR
												MDR N	MDR %		MDR N	MDR %	
Genetu *et al.* [68]	BahrDar	Amhara	Pre-print	HIV patients	Patients Suspected of Pneumonia	Pneumonia	Sputum	163	9	5.5	3	2	66.7	6	4	66.7	66.7
Worku et al. [69]	Multi-center	Ethiopia	2023	All age groups	Hospitalized patients	SSI	Clinical samples	752	62	8.2	19	14	73.8	43	40	93	87.1
Legese et al. [70]	Multi-center	Ethiopia	2022	All age groups	Blood stream infections	Sepsis	Blood samples	1416	61	4.3	19	9	47.5		35	83.4	72.1
Birru et al. [71]	Arbamich	SNNR	2021	Age ≥ 18 years	Blood stream infections	Sepsis	Blood samples	225	2	0.9	2	2	50				50
Tadesse et al [45]	Woldia	Amhara	2023	All age groups	Out patients	CAI	Clinical samples	384	30	7.8	10	10	100	20	20	100	100
Teweldmedhin et al. [72]	Mekele	Tigray	2017	All age groups	ENT suspected patients	Ear infections	Ear discharge	270	26	9.6	21	21	100	5	5	100	100
Motbainor et al. [73]	BahrDar	Amhara	2020	All age groups	Hospitalized patients	HAI	clinical samples:	238	20	8.4	11	11	100	9	9	100	100
Assefa et al. [74]	Gondar	Amhara	2015	All age groups	ENT suspected patients	Ear infections	Ear discharge	51	3	5.9	3	2	66.7				66.7
Ejerssa, et al. [75]	Harar	Harar	2021	Pregnant women	Patients Suspected of UTI	UTI	Clean catch mid-stream	200	2	1	2	2	100				100
Mulu et al. [76]	Debre-Markos	Amhara	2017	All age groups	Hospitalized patients	HAI	Clinical samples:	575	30	5.2	30	22	73.3				
Belayhun et al. [77]	Gondar	Amhara	2018	All age groups	ENT suspected patients	Ear infections	Ear discharge	210	14	6.7	14	7	50				66.7
Wasihun et al. [78]	Mekele	Tigray	2015	All age groups	ENT suspected patients	Ear infections	Ear discharge	162	27	16.7	27	23	85.2				85.2
Sewunet et al. [79]	Jimma	Oromia	2022	All age groups	Out patients	CAI	clinical samples	1087	80	7.4	41	35	83.4	39	30	76.9	81.3
Tekele et al. [80]	Addis Ababa	Addis Ababa	2020	All age groups	Out patients	CAI	clinical samples	338	26	7.7	17	17	100	9	8	88.9	96.2

Table 1 (continued)

Author	Study area	Region	Publication year	Study population	Type of patients	Type of infections	Sample types (Culture specimens)	Sample size	Total pathogen isolated	Prevalence (%)	Pseudomonas Spp	Pseudomonas Spp		Acinetobacter spp	Acinetobacter spp		Total MDR
												MDR N	MDR %		MDR N	MDR %	
Mekonnen et al. [81]	Dessie	Amhara	2022	All age groups	Hospitalized patients	HAI	clinical samples:	254	34	13.4	18	15	83.3	16	13	83.3	82.4
Hailemariam et al. [82]	Hawassa	Sidama	2021	All age groups	Out patients	CAI	clinical samples:	1085	52	4.8	35	25	71.4	17	12	70	71.2
Kefeni et al. [83]	Hawassa	Sidama	2024	All age groups	Patients Suspected of UTI	UTI	Clean catch mid-stream	149	5	3.4	3	3	100	2	2	100	100
Awoke et al. [84]	Jimma	Oromia	2019	All age groups	Patients Suspected of UTI	UTI	Clean catch mid-stream	143	3	2.1	3	3	100				100
Abdeta et al. [85]	Addis Ababa	Addis Ababa	2021	All age groups	Out patients	CAI	clinical samples:	1337	110	8.2	36	10	27.8	74	52	70.3	56.4
Addis et al. [86]	Addis Ababa	Addis Ababa	2021	All age groups	Patients Suspected of UTI	UTI	Clean catch mid-stream	1012	20	2	8	5	62.5	12	11	91.7	80
Mitiku et al. [87]	Arbamich	SNNR	2022	All age groups	Patients Suspected of UTI	UTI	Clean catch mid-stream	422	16	3.8	16	10	62.5				
Seid et al. [88]	Arbamich	SNNR	2023	All age groups	Patients Suspected of UTI	UTI	Clean catch mid-stream	62	3	4.8	3	2	66.7				
Oumer et al. [89]	Kombolcha	Amhara	2022	Age ≥ 18 years	Patients Suspected of UTI	UTI	Clean catch mid-stream	282	10	3.5	3	8	80				
Guteta et al. [90]	Nekemte	Oromia	Pre-print	All age groups	ENT suspected patients	Ear infections	Ear discharge	242	39	16.1	33	25	75.8	6			100
Gebremedhin et al. [91]	Mekele	Tigray	2023	All age groups	Patients Suspected of UTI	UTI	Clean catch mid-stream	297	10	3.4	10	8	80				85.2
Abate et al. [92]	Harar	Harari	2020	Age ≥ 18 years	Patients Suspected of UTI	UTI	clinical samples:	207	12	5.8	12	10	83.3				85.2

Table 2 Individual pooled prevalence of *Pseudomonas* and *Acinetobacter species* in Ethiopia

Author	*Pseudomonas* spp. Effect [95% CI]	*Acinetobacter species* Effect [95% CI]	Overall pooled Prevalence Effect [95% CI]
Abera *et al* [30]	148.0 (145.57–150.43)	-	148.0 (145.57–150.43)
Dereje et al. [31]	4.00 (2.15–5.85)	-	4.00 (2.15–5.85)
Misha et al. [32]	8.00 (5.82–10.18)	-	8.00 (5.82–10.18)
Endaylalu et al. [33]	54.00 (48.64–59.36)	-	54.00 (48.64–59.36)
Getaneh et al. [34]	24.00 (21.01–26.99)	11.00(8.01–13.99)	35.00 (32.01–37.99)
Gorems et al. [35]	19.00 (14.34–23.66)	-	19.00 (14.34–23.66)
Hailu et al. [36]	88.00 (83.64–92.34)	-	88.00 (83.64–92.34)
Gashaw et al. [37]	9.00 (6.35–11.65)	2.00 (−0.65–4.65)	11.00 (8.35–13.65)
Chernet et al. [38]	4.00 (2.70–5.30)	-	4.00 (2.70–5.30)
Molla et al. [39]	2.00 (2.38–6.38)	-	2.00 (2.38–6.38)
Muluye et al. [40]	18.00 (13.43–22.57)	15.00 (10.43–19.57)	33.00 (28.43–37.57)
Muleta et al. [41]	18.00 (13.37- 22.63)	-	18.00 (13.37- 22.63)
Hailegiyorgis et al. [42]	11.00 (7.120–14.88)	-	11.00 (7.120–14.88)
Tolera et al. [43]	6.00 (4.79–7.21)	-	6.00 (4.79–7.21)
Seid et al. [44]	30.00 (24.84–35.16)	-	30.00 (24.84–35.16)
Tadesse et al. [45]	6.00 (2.44- 9.56)	2.00 (−1.56–5.56)	8.00 (4.44–11.56)
Girma et al. [46]	8.00 (4.17–11.83)	-	8.00 (4.17–11.83)
Negash et al. [47]	3.00 (2.29–3.71)	1.00 (0.29–1.71)	4.00 (3.29–4.71)
Nurahmed et al. [48]	7.00 (4.73- 9.27)	1.00(−1.27–3.27)	8.00 (5.73–10.27)
Hailu et al. [49]	27.00 (24.42–29.58)	-	27.00 (24.42–29.58)
Regassa et al. [50]	12.00 (8.14–15.86)	-	12.00 (8.14–15.86)
Atlaw et al. [51]	24.00 (16.31–31.69)	12.00 (4.31–19.69)	36.00 (28.31–43.69)
Sisay et al. [52]	15.00 (12.99–17.00)	1.00(−1.01–3.01)	16.00 (13.99–18.01)
Gebre et al. [53]	25.00 (21.98–28.01)	19.00 (5.98–22.02)	44.00 (40.98–47.02)
Temesgen et al. [54]	19.00 (16.982–21.02)	-	19.00 (16.982–21.02)
Tilahun et al. [55]	34.00 (31.04–36.96)	2.00(−0.956–4.96)	36.00 (33.04–38.96)
Dessie et al. [56]	22.00 (19.65–24.35)	3.00(0.65–5.35)	25.00 (22.65–27.35)
Haile et al. [57]	22.00 (21.04–22.96)	3.00 (2.04–3.96)	22.00 (17.80–26.20)
Moges et al. [58]	6.00 (5.43- 6.57)	-	6.00 (5.43- 6.57)
Assefa et al. [59]	5.00 (3.61- 6.39)	-	5.00 (3.61- 6.39)
Asmare et al. [60]	6.00 (4.49–7.51)	2.00 (0.49–3.51)	8.00 (6.49–9.51)
Alebel et al. [61]	11.00 (7.60–14.40)	13.00(9.60–16.40)	24.00 (20.60–27.40)
Henok et al. [62]	13.00 (10.49–15.51)	4.00 (1.49–6.51)	17.00 (14.49–19.51)
Alelign et al. [63]	13.00 (10.38–15.62)	-	13.00 (10.38–15.62)
Tilahun et al. [9]	46.00 (42.36–49.64)	29.00 (25.36–32.64)	75.00 (71.36–78.64)
Tilahun et al. [64]	31.00 (28.15–33.85)	3.00 (0.15–5.85)	34.00 (31.15–36.85)
Regasa, et al. [65]	10.00 (5.52–14.48)	-	10.00 (5.52–14.48)
Adugna, et al. [66]	3.00 (2.08–3.92)	-	3.00 (2.08–3.92)
Adhanom et al. [67]	46.00(44.45–47.55)	-	46.00(44.45–47.55)
Genetu *et al.* [68]	3.00(−0.50- 6.50)	6.00 (2.50- 9.50)	4.00 (2.45–5.55)
Worku et al. [69]	19.00 (17.04–20.96)	43.00 (41.04–44.96)	62.00 (60.04–63.96)
Legese et al. [70]	19.00 (17.94–20.06)	-	19.00 (17.94–20.06)
Birru et al. [71]	2.00 (0.77–3.23)	-	2.00 (0.77–3.23)
Tadesse et al [45]	10.00 (7.32- 12.68)	20.00 (17.32–22.68)	30.00 (27.32–32.68)
Teweldmedhin et al. [72]	21.00 (17.49–24.51)	5.00 (1.49- 8.51)	26.00 (22.49–29.51)
Motbainor et al. [73]	11.00 (7.48–14.52)	9.00 (5.48–12.52)	20.00 (16.48–23.52)
Assefa et al. [74]	3.00 (−3.48–9.48)	-	3.00 (−3.48–9.48)
Ejerssa, et al. [75]	2.00 (0.62- 3.38)	-	2.00 (0.62- 3.38)
Mulu et al. [76]	8.00(5.82- 10.18)	-	8.00(5.82- 10.18)

Table 2 (continued)

Author	*Pseudomonas* spp. Effect [95% CI]	*Acinetobacter species* Effect [95% CI]	Overall pooled Prevalence Effect [95% CI]
Belayhun et al. [77]	30.00 (28.18–31.82)	-	30.00 (28.18–31.82)
Wasihun et al. [78]	14.00 (10.618 17.382	-	14.00 (10.618–17.382
Sewunet et al. [79]	27.00 (21.26–32.74)	-	27.00 (21.26–32.74)
Tekele et al. [80]	41.00 (39.44–42.56)	39.00 (37.44–40.56)	80.00 (78.44–81.56)
Mekonnen et al. [81]	17.00 (14.16- 19.84)	9.00 (6.16–11.84)	26.00 (23.16–28.84)
Hailemariam et al. [82]	18.00 (13.81- 22.19)	16.00 (11.81–20.19)	34.00 (29.81–38.19)
Kefeni et al. [83]	35.00 (33.73–36.27)	17.00 (15.73–18.27)	52.00 (50.73–53.27)
Awoke et al. [84]	3.00 (0.09- 5.91)	2.00 (–0.91- 4.91)	5.00 (2.09–7.91)
Abdeta et al. [85]	3.00 (0.65–5.35)	-	3.00 (0.65–5.35)
Addis et al. [86]	36.00 (34.53- 37.47)	74.00 (2.53–75.47)	110.00 (108.53–111.47)
Mitiku et al. [87]	8.00 (7.14- 8.86)	12.00 (11.14–12.86)	20.00 (19.14–20.86)
Seid et al. [88]	16.00 (14.18–17.82)	-	16.00 (14.18–17.82)
Oumer et al. [89]	3.00 (–2.32- 8.32)	-	3.00 (–2.32- 8.32)
Guteta et al. [90]	3.00 (0.86–5.15)	-	10.00 (7.86–12.15)
Gebremedhin et al. [91]	33.00 (28.37–37.63)	6.00 (1.37- 10.63)	39.00 (34.37–43.63)
Abate et al. [92]	10.00 (7.94–12.06)	-	10.00 (7.94–12.06)
Abera *et al* [30]	11.00 (7.37–14.63)	5.00 (1.37- 8.63)	16.00 (12.37–19.63)
Overall	**19.12(14.86–23.38)**	**12.46 (5.82–19.10)**	**25.31 (18.61–32.00)**
I^2 (%)	**99.7%**	**99.7%**	**99.9%**
***P* value**	**< 0.001**	**< 0.001**	**< 0.001**

(144), and community-acquired infections (139) from the total study collected [18–29] (Table 1).

Pooled prevalence of *Pseudomonas and Acinetobacter species* in Ethiopia

In this systematic review and meta-analysis, the pooled prevalence of *Pseudomonas* and *Acinetobacter species* in Ethiopia was found to be 19.12 (95% CI: 14.86–23.38) and 12.46 (95% CI: 5.82–19.10), respectively (Table 2). The overall pooled prevalence *Pseudomonas* and *Acinetobacter* species was 25.31 (95% CI: 18.61–32.00). High heterogeneity was detected among the studies ($I^2 = 93.6\%$, $p < 0.001$).

Subgroup analysis

Subgroup analysis of *Pseudomonas* and *Acinetobacter* species in clinical samples revealed significant variations in prevalence based on different factors. Regarding age groups, the pooled prevalence for all age groups was 7.78% (95% CI: 6.52–9.02), with substantial heterogeneity ($I^2 = 74.7\%$, $p = 0.003$). For children under 15 years, the prevalence was 5.92% (95% CI: 1.94–9.89), and for adults, it was 4.57% (95% CI: 2.21–6.94), both showing high heterogeneity ($I^2 = 91.6\%$ and 87.5%, respectively, with $p < 0.001$). This indicates statistically significant differences in the prevalence across these age groups.

Analysis by publication year showed that studies published before 2021 had a higher pooled prevalence of 8.30% (95% CI: 6.59–10.01), while studies from 2021 and beyond reported a lower prevalence of 5.49% (95% CI: 4.35–6.64). The heterogeneity between groups for publication year was statistically significant ($p = 0.007$). When considering geographical regions, significant differences were observed in prevalence rates, with the highest prevalence in the Amhara region (8.34%, 95% CI: 6.53–10.15) and the lowest in Harari (2.69%, 95% CI: 0.25–5.13). Other regions like Addis Ababa, Oromia, and Tigray showed prevalence rates ranging from 5.99% to 7.11%, with all regional differences being statistically significant ($p < 0.001$).

In terms of sample types, ear discharge and pus aspirates/wound swabs exhibited the highest pooled prevalences of 11.74% (95% CI: 9.10–14.38) and 11.44% (95% CI: 3.30–19.60), respectively. Sputum samples had a prevalence of 4.83% (95% CI: 2.86–6.80), while blood samples and ascitic fluid showed lower prevalences

Table 3 Subgroup analysis of *Pseudomonas* and *Acinetobacter* species in clinical sample

Subgroups	Category	No of studies	No of isolates tested, N	Pooled prevalence of N (%)	95% CI	Heterogeneity test (I^2)	*P*-value	Heterogeneity between groups (*p*-value)
Type of samples	Ear discharge	18		11.74	(9.10,14.38)	87.7%	< 0.001	< 0.001
	Clean catch mid-stream urine	11		2.365	(1.59,3.14)	50.2%	< 0.001	
	pus aspirates, and wound swab	3		11.44	(3.30,19.60)	94.7%	< 0.001	
	Clinical sample	19		6.518	(4.80,8.23)	94.8%	< 0.001	
	Sputum	10		4.828	(2.86,6.80)	90.9%	< 0.001	
	Ascitic fluid	1		2.70	(0.08, 5.32)	0	-	
	Sputum and Blood	1		7.50	(3.02,11.98)	0	-	
	Blood samples	2		2.62	(−0.72, 5.95)	94.1%	< 0.001	
	Total pooled	65		6.78	(5.82,7.74)	93.6%%	< 0.001	
Region	Addis Ababa	8		5.99	(3.40, 8.57)	95.3%	< 0.001	< 0.001
	Amhara	30		8.34	(6.53,10.15)	95.3%	< 0.001	
	Oromia	9		6.62	(3.94,9.30)	90.2%	< 0.001	
	Tigray	4		7.105	(2.42,11.79)	92.0%	< 0.001	
	Harari	3		2.69	(0.25,5.13)	82.7%	0.003	
	Sidama	4		5.40	(3.14,8.85)	79.9%	0.002	
	SNNPR	5		3.209	(1.29, 5.13)	72%	0.007	
	Different part of Ethiopia	2		6.12	(2.34,9.98)	92%	0.001	
	Total pooled	65		6.78	(5.82,7.74)	93.6%%	< 0.001	
Publication year	< 2021	8		8.30	(6.59,10.01)	94.2%	< 0.001	0.007
	≥ 2021	9		5.49	(4.35,6.64)	93.0%	< 0.001	
	Total pooled	65		6.78	(5.82,7.74)	93.6%%	< 0.001	
Study population type	All age groups	45		7.78	(6.52, 9.02)	74.7%	0.003	< 0.001
	Children < 15 years	7		5.92	(1.94, 9.89)	91.6%	< 0.001	
	Adult Patients	13		4.573	(2.21, 6.94)	87.5%%	< 0.001	
	Total pooled	65		6.78	(5.82,7.74)	93.6%%	< 0.001	
Sample size	< 300	38		7.224	(5.84, 8.61)	88.6%	< 0.001	0.132
	≥ 300	27		6.199	(4.80, 7.59)	96.0%	< 0.001	
	Total pooled	65		6.78	(5.82,7.74)	93.6%%	< 0.001	

of 2.62% (95% CI: −0.72 to 5.95) and 2.70% (95% CI: 0.08–5.32). The total pooled prevalence across all sample types was 6.78% (95% CI: 5.82–7.74), with high heterogeneity ($I^2 = 93.6\%$, $p < 0.001$).

Finally, the sample size also appeared to influence the prevalence rates. Studies with sample sizes less than 300 had a pooled prevalence of 7.22% (95% CI: 5.84–8.61), while studies with larger sample sizes (≥ 300) reported a slightly lower pooled prevalence of 6.20% (95% CI: 4.80–7.59). The heterogeneity between groups was not significant for this comparison ($p = 0.132$) (Table 3).

Pooled drug resistance profile for *Pseudomonas and Acinetobacter species* in Ethiopia

In this systematic review and meta-analysis, the pooled resistance profiles for *Pseudomonas* species in Ethiopia were as follows: amoxicillin-clavulanic acid resistance was 83.73% (95% CI: 78.79–88.67), tetracycline 89.15% (95% CI: 82.17–108.12), amikacin 37.74% (95% CI: 30.21–45.27), gentamicin 47.68% (95% CI: 39.16–56.20), chloramphenicol 58.69% (95% CI: 51.27–66.11), SXT 65.58% (95% CI: 59.33–71.82), ciprofloxacin 37.66% (95% CI: 32.94–42.38), ampicillin 84.01% (95% CI: 76.66–91.35), ceftriaxone 57.30% (95% CI: 50.30–64.30), cefotaxime

Table 4 Individual pooled prevalence of *Pseudomonas* in Ethiopia

Author	*Pseudomonas* spp.					
	AMC Effect [95% CI]	TE Effect [95% CI]	AMK Effect [95% CI]	GN Effect [95% CI]	C Effect [95% CI]	SXT Effect [95% CI]
Abera *et al* [30]	-	84.00 (81.57–86.43)	30.40 (27.97–32.83)	30.400 (27.97–32.83)	69.70 (67.27- 72.13)	70.00 (67.57–72.43)
Dereje *et al* [31]	80.00 (78.15–81.85)	50.00 (48.15–51.85)	25.00 (23.15–26.85)	25.00 (23.15–26.85)	20.00 (18.15–21.85)	
Misha *et al* [32]	100.00 (97.82–102.18)	100.00 (97.82–102.18)	37.50 (35.32–39.68)	37.50 (35.32–39.68)	75.00 (72.82–77.18)	75.00 (72.82–77.18)
Endaylalu *et al* [33]	74.10 (68.74–79.46)	100.00(94.64–105.36)	15.00 (9.64–20.36)	29.60 (24.24–34.96)	85.20 (79.84–90.56)	31.50 (26.14–36.86)
Getaneh *et al* [34]	85.00 (82.01–87.99)	78.00 (75.01–80.99)	35.00 (32.01–37.99)	34.00 (31.01–36.99)	65.00 (62.01–67.99)	25.00 (22.01–27.99)
Gorems et al [35]	85.00 (80.34–89.66)	100.00 (95.34–104.66)	21.40 (16.74–26.06)	14.30 (9.638–18.96)		
Hailu *et al* [36]	89.00 (84.64–93.36)	98.90 (94.54–103.24)	4.50 (0.143- 8.85)	10.20 (5.84–14.56)	6.80 (2.44–11.16)	0.00 (–4.36-4.36)
Gashaw *et al* [37]	100.00 (97.35–102.65)	100.00 (97.35–102.65)	55.60 (52.95–58.25)	88.90 (86.250–91.55)	100.00(97.35–102.65)	44.40 (41.75–47.05)
Chernet *et al* [38]		75.00 (73.70–76.30)				
Molla *et al* [39]	100.00 (95.62–104.38)	100.00 (95.62–104.38)	50.00 (45.62–54.38)	50.00 (45.62–54.40)	100.00 (95.62–104.38)	100.00 (95.62–104.38)
Muluye *et al* [40]	77.80(73.23–82.37)	77.80 (73.23- 82.37)	50.00 (45.43–54.57)	33.30 (28.73–37.87)	77.80 (73.23–82.37)	66.70 (62.13–71.27)
Muleta *et al* [41]		94.40 (89.77–99.03)	44.40 (39.77–49.03)	44.40 (39.77–49.03)	61.10 (56.47- 65.730	66.70 (62.07–71.33)
Hailegiyorgis *et al* [42]		90.90 (87.02–94.78)	27.30 (23.42–31.18)	27.30 (23.420 –31.18)	57.90 (54.02–61.78)	57.80 (53.92–61.68)
Tolera *et al* [43]		100.00 (98.79–101.20)	33.30 (32.09–34.51)	33.30 (32.092–34.51)	66.70 (65.49–67.91)	50.00 (48.792–51.21)
Seid *et al* [44]		96.70 (91.54–101.86)	33.30 (28.14–38.46)	33.30 (28.141–38.46)	66.70 (61.54–71.86)	63.30 (58.14–68.46)
Tadesse *et al* [45]		100.00 (96.40–103.56)	25.00 (21.44–28.56)	25.00 (21.44–28.56)	33.30 (29.74–36.86)	66.70 (63.14–70.26)
Girma *et al* [46]	25.00 (21.17–28.83)	87.50 (83.67–91.33)	37.50 (33.67–41.34)	37.50 (33.67–41.33)	75.00 (71.17–78.83)	75.00 (71.17–78.83)
Negash [47]	66.70 (65.99- 67.41)	75.00 (74.29–75.71)			33.30 (32.59–34.01)	66.70 (65.99–67.41)
Nurahmed *et al* [48]	71.00 (68.73–73.27)	71.00 (68.73–73.27)	29.00 (26.73–31.27)	43.00 (40.730–45.27)	42.90 (40.63–45.17)	14.00 (11.73–16.27)
Hailu *et al* [49]	92.30 (89.72–94.88)	92.30 (89.72–94.88)	7.70 (5.12- 10.28)	30.40 (27.82–32.98)	44.40 (41.82–46.98)	33.30 (30.72–35.88)
Regassa *et al* [50]	91.70 (87.84–95.56)	91.70 (87.84–95.56)	7.70 (3.84–11.56)	30.40 (26.54–34.26)	41.70 (37.84–45.56)	33.30 (29.44–37.16)
Atlaw *et al* [51]	100.00 (92.31–107.69)	95.83(88.14–103.52)	54.20 (46.51–61.89)	44.50 (42.49–46.51)	83.30 (75.61–90.99)	87.50 (79.81–95.19)
Sisay *et al* [52]	93.30 (91.29–95.31)	93.30 (91.29–95.31)	44.50 (42.49–46.51)		66.70 (64.69–68.71)	
Gebre *et al* [53]	96.00 (92.98–99.02)	96.00 (92.98–99.02	20.00 (16.98–23.02)	32.00 (28.98–35.02)	35.00 (31.98–38.02)	80.00 (76.98–83.02)
Temesgen *et al* [54]	94.70 (92.68–96.70)	94.70 (92.68–96.72)	26.30 (24.28–28.32)	57.90 (55.88–59.92)	42.10 (40.08–44.12)	68.40 (66.38–70.42)
Tilahun *et al* [55]	88.20 (85.24–91.12)	91.20 (90.10–91.50)	44.20 (41.24–47.16)	58.80 (55.84–61.76)	32.40 (29.44–35.36)	73.50 (70.54–76.46)
Dessie *et al* [56]	86.40 (84.05–88.74)	90.90 (88.55–93.25)	9.10 (6.75–11.45)	54.50 (52.15–56.85)	100.00 (97.65–102.35)	100.00 (97.65–102.32)
Haile *et al* [57]	100.00 (99.04–100.96)	100.00 (99.04–100.96)	9.10 (8.14–10.06)	54.50 (53.54–55.46)	100.00 (95.80–104.20)	100.00 (95.80–104.20)
Moges *et al* [58]		100.00 (98.61–101.39)	50.00 (49.43–50.57)	100.00 (99.43–100.56)	100.00 (99.43–100.57)	100.00 (99.43–100.57)
Assefa *et al* [59]	100.00 (98.61–101.39)	100.00 (98.49–101.51)		80.00 (78.61–81.39)	100.00 (98.49–101.51)	
Asmare *et al* [60]	100.00 (98.49–101.51)	100.00(98.49- 101.5)	100.00 (98.49–101.51)	100.00 (98.49–101.50)	100.00 (96.60–103.40)	100.00 (98.49–101.51)
Alebel *et al* [61]	100.00 (96.60–103.40)	100.0 (96.60- 103.40)	72.70 (69.304–76.10)	100.00 (96.60–103.40)	53.80 (51.29–56.31)	100.00 (96.60–103.40)
Henok et al [62]	76.90 (74.39–79.41)	-	23.00 (20.49–25.508	15.30(12.79 –17.81)	50.00 (47.38–52.62)	23.00 (20.49–25.51)
Alelign *et al* [63]	100.00 (97.38–102.62)	100.00 (97.38–102.62)		25.00 (22.38–27.62)		
Tilahun *et al* [9]	97.80 (94.16–101.44)	97.80 (94.163–101.43)	34.80 (31.16–38.44)	43.50 (39.86–47.12)	78.30 (74.66–81.94)	84.80 (81.163–88.44)
Tilahun *et al* [64]	91.20 (88.35–94.05)	91.20 (88.35–94.05)	58.10 (55.25–60.95)	38.70 (35.85–41.55)	80.60 (77.75–83.45)	80.60 (77.75–83.45)
Regasa, *et al* [65]			50.00 (45.52–54.48)	50.00 (45.52–54.48)	30.00 (25.52–34.48)	100.00 (95.52–104.48)

Table 4 (continued)

Adugna, *et al* [66]	75.00 (74.08–75.92)	75.00 (74.08–75.92)	33.30 (32.38–34.22)	33.30 (32.38–34.22)	33.30 (32.38–34.22)	66.70 (65.78–67.62)
Adhanom *et al* [67]			25.00 (23.45–26.55)	25.00 (23.45–26.55)	50.00 (48.45–51.55)	75.00 (73.45–76.55)
Genetu *et al* [68]	100.00(96.50–103.50)	100.00 (96.50–103.50)	33.30 (29.80–36.80)	33.30 (29.80–36.80)		66.70 (63.20–70.20)
Worku *et al* [69]			21.10 (19.14–23.06)	47.30 (45.34–49.26)	47.30 (45.34–49.26)	68.40 (66.44–70.36)
Legese *et al* [70]		63.20 (62.14–64.26)	5.30 (4.24–6.36)	31.60 (30.54–32.66)	31.60 (30.54–32.66)	52.60 (51.54–53.66)
Birru *et al* [71]				50.00 (48.77–51.23)		
Tadesse *et al* [45]	100.00 (97.32–102.68)		20.00 (7.32–22.68)	100.00 (97.32–102.68)	100.00 (97.32–102.68)	60.00 (57.32–62.68)
Teweldmedhin et al [72]	100.00 (96.49–103.51)			80.00 (76.49–83.51)	80.00 (76.49–83.51)	60.00 (56.49–63.51)
Motbainor *et al* [73]	100.00 (96.48–103.52)	90.90(87.40- 94.42)	54.50 (50.98–58.02)	54.50 (50.99–58.02)		100.00 (96.48–103.52)
Assefa *et al* [74]	66.70 (60.23–73.18)	33.30(26.83–39.70)			33.30 (26.83- 39.77)	33.30 (26.83- 39.77)
Ejerssa, *et al* [75]	100.00 (98.62–101.38)				50.00 (48.62–51.38)	100.00 (98.62–101.38)
Mulu *et al* [76]	33.30 (31.49- 35.11)	57.50 (55.69–59.34)	35.50 (33.69–37.32)	87.50 (85.69–89.32)	23.10 (21.29–24.92)	50.00 (48.19–51.82)
Belayhun *et al* [77]	50.00 (46.62–53.38)	71.40 (68.02–74.78)	21.40 (18.02–24.78)		28.60 (25.22–31.98)	64.30 (60.92–67.68)
Wasihun *et al* [78]	88.90 (83.16–94.64)	100.00 (94.26–105.74)	62.30 (56.56–68.04)	62.30 (56.56–68.04)	62.30 (56.56–68.04)	70.40 (64.66–76.14)
Sewunet *et al* [79]	32.40 (30.84–33.97)	83.40 (81.84–84.96)		11.80 (8.96–14.64)	50.00 (48.44–51.56)	66.60 (65.04–68.16)
Tekele *et al* [80]	100.00 (97.16–102.84)	100.00 (97.16–102.84)	11.80 (8.95–14.64)		11.80 (8.96–14.64)	100.00 (97.16–102.84)
Mekonnen *et al* [81]	72.20 (68.01–76.39)	72.20 (68.011–76.39)	11.10 (6.91–15.29)	27.80 (23.61–31.99)	68.60 (64.41- 72.79	68.60 (64.41–72.79)
Hailemariam *et al* [82]	68.60 (67.33–69.87)		51.40 (50.13–52.67)	11.40 (10.13–12.67)	25.70 (24.43–26.97)	34.30 (3.03–35.57)
Kefeni *et al* [83]	100.00 (97.09–102.91)	100.00 (97.09–102.91)	100 (97.090- 102.91)	100.00 (97.10–102.91)	100.00 (97.09–102.91)	66.70 (63.79–69.61)
Awoke *et al* [84]	66.70 (64.35–69.05)	100.00 (97.65–102.3)	25.00 (22.65–27.35)	25.00 (22.65–27.35)	66.70 (64.35–69.05)	66.70 (64.35–69.05)
Abdeta *et al* [85]	75.00(73.53–76.47)		4.30 (2.83–5.77)	4.30 (2.83–5.77)	69.40 (67.93–70.87)	32.20 (30.73–33.67)
Addis *et al* [86]	75.00 (74.14–75.86)		100.00 (99.14–100.86)	100.00 (99.14–100.86)	50.00 (49.14–50.86)	75.00 (74.14–75.86)
Mitiku *et al* [87]	75.00 (73.18–76.82)		75.00 (73.178–76.82)	75.00 (73.18–76.82)	25.00 (23.18- 26.82)	19.90 (18.08–21.72)
Seid *et al* [88]	66.60 (61.28–71.92)		33.30 (27.98–38.62)	33.30 (27.98–38.62)	33.30 (27.98–38.62)	
Oumer *et al* [89]	66.70 (64.56- 68.85)		66.70 (64.56–68.85)	66.70 (64.56–68.85)		66.70 (64.56–68.85)
Guteta *et al* [90]	90.00 (87.94–92.06)	60.60 (55.97–65.23)	60.60 (55.97- 65.23)	60.60(55.97- 65.23)	66.70 (62.10–71.33)	66.70 (62.07–71.33)
Gebremedhin *et al* [91]	90.00 (87.94–92.06)	100.00 (97.94–102.06)	70.00 (67.94–72.06)	40.00 (37.94–42.06)	40.00 (37.94–42.06)	70.00 (67.94–72.06)
Abate et al [92]	91.60 (87.97–95.23)	100.00 (96.37–103.63)	27.30 (23.68–30.93)	91.60 (87.97–95.23)	83.30 (79.67–86.93)	100.00 (96.37–103.63)
Overall	**83.73 (78.72–88.74)**	**89.15 (82.17–108.12)**	**37.74 (30.21–45.27)**	**47.68 (39.16–56.20)**	**58.69 (51.27–66.11)**	**65.58 (59.33–71.82)**
I^2 (%)	**99.7%**	**100.0%**	**99.9%**	**99.9%**	**99.7%**	**99.8%**
***P*value**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Author	*Pseudomonas* spp.					
	CIP Effect [95% CI]	AMP Effect [95% CI]	CRO Effect [95% CI]	CXT Effect [95% CI]	CAZ Effect [95% CI]	MEM Effect [95% CI]
Abera *et al* [30]	3.50 (1.07–5.93)	91.80 (89.37–94.23)	53.70 (51.27–56.13)	54.00 (51.57–56.43)	45.00 (42.57- 47.43)	25.00 (22.57–27.43)
Dereje *et al* [31]	20.00 (18.15–21.85)		0.00 (−1.85-1.85)			
Misha *et al* [32]	37.50 (35.32–39.68)	100.00 (97.82–102.18)	37.50 (35.32–39.68)	37.50 (5.32–39.68)	37.50 (35.32–39.68)	37.50 (35.32–39.68)
Endaylalu *et al* [33]	5.60 (0.24–10.96)	96.30 (90.94–101.66)	22.10 (16.74–27.46)	11.10 (5.74–16.46)	16.70 (11.34–22.06)	
Getaneh *et al* [34]	56.00 (53.01–58.99)		42.00 (39.01–44.99)	45.00 (42.01–47.99)	62.00 (59.01–64.99)	35.00 (32.01–37.99)

Table 4 (continued)

Gorems et al [35]	21.40 (16.74–26.06)		100.00 (95.34–104.66)		71.40 (66.74–76.06)	
Hailu *et al* [36]	8.00 (3.64–12.36)	90.90 (86.54–95.26)	23.00 (18.64–27.36)	24.00 (19.64–28.36)	31.80 (27.44–36.16)	
Gashaw *et al* [37]	66.70 (64.05–69.35)	100.00 (97.35–102.65)	100.00 (97.35–102.65)		100.00 (97.35–102.65)	44.40 (41.75–47.05)
Chernet *et al* [38]						
Molla *et al* [39]	0.00 (−4.38- 4.38)	100.00 (95.62–104.38)	100.00 (95.62–104.38)	100.00(95.62–104.38)	50.00 (45.62–54.38)	50.00 (45.62–54.38)
Muluye *et al* [40]	16.70 (12.13–21.27)	77.80 (73.23–82.37)	33.30 (28.73–37.87)	35.50 (30.930–40.07)	25.00 (20.43–29.57)	
Hailegiyorgis *et al* [42]						
Tolera *et al* [43]	33.30 (32.09–34.51)		50.00 (48.79–51.21)	50.00 (48.79–51.21)	83.70 (82.49–84.91)	
Seid *et al* [44]	33.30 (28.14–38.46)		50.00 (44.84–55.16)	50.00 (44.84–55.16)	83.70 (78.54–88.86)	
Tadesse *et al* [45]	16.70 (13.14- 20.26)		100.00 (96.44–103.56)	100.00 (96.44–103.56)	25.00 (21.44–28.56)	25.00 (21.44–28.56)
Girma *et al* [46]	37.50 (33.67–41.33)	75.00 (71.173–78.83)	50.00 (46.17–53.83)	50.00 (46.17–53.83)	37.50 (33.67–41.33)	50.00 (46.17–53.83)
Negash [47]	66.70 (65.99–67.41)	66.70 (65.99–67.41)	66.70 (65.99–67.41)	66.70 (65.99–67.41)	37.50 (36.79–38.21)	50.00 (49.29–50.71)
Nurahmed *et al* [48]	14.00 (11.73–16.27)		29.00 (26.73–31.27)	29.00 (26.73–31.27)	71.00 (68.73–73.27)	14.00 (11.73–16.27)
Hailu *et al* [49]	19.20 (16.62–21.78)			-	71.30 (68.72–73.88)	33.30 (30.72–35.88)
Regassa *et al* [50]	19.20 (15.34–23.06)			-	71.30 (67.44–75.16)	33.30 (29.44–37.16)
Atlaw *et al* [51]	54.20 (46.51–61.89)		83.30 (75.61–90.99)	87.50 (79.81–95.19)	54.20 (46.51–61.89)	37.50 (29.81–45.19)
Sisay *et al* [52]	60.00 (57.99–62.01)	93.30 (91.29–95.31)	83.30 (81.29–85.31)	60.00 (57.99–62.01)		
Gebre *et al* [53]	32.00 (28.98–35.02)			65.00 (61.98–68.02)	76.00 (72.98–79.02)	
Temesgen *et al* [54]	21.10 (19.08–23.12)		26.30 (24.28–28.32)	-	5.30 (3.28–7.32)	
Tilahun *et al* [55]	61.80 (58.84–64.77)		55.90 (52.94–58.86)	55.90 (52.94–58.86)	64.70 (61.74–67.66)	41.20 (38.24–44.16)
Dessie *et al* [56]	4.50 (2.15–6.87)			-	63.60 (61.25–65.95)	9.10 (6.75–11.45)
Haile *et al* [57]	4.50 (0.30–8.70)		50.00 (49.43–50.57)	-	63.60 (59.40–67.80)	9.10 (4.90–13.30)
Moges *et al* [58]	50.00 (49.43–50.57)		100.00 (98.49–101.51)	100.00 (99.43–100.57)	100.00 (99.43–100.57)	50.00 (49.43–50.57)
Assefa *et al* [59]	20.00 (18.61–21.39)				80.00 (78.61- 81.39)	
Asmare *et al* [60]	50.00 (8.49–51.51)		100.00 (98.49–101.51)	100.00 (98.49–101.51)	50.00 (48.49–51.51)	50.00 (48.49–51.510
Alebel *et al* [61]	45.50 (42.10–48.90)		100.00 (96.61–103.40)	100.00 (96.60–103.40)	100.00 (96.60–103.40)	8.20 (4.80–11.60)
Henok et al [62]	76.90 (74.39–79.41)			53.80 (51.29–56.31)	-	38.40 (35.89–40.91)
Alelign *et al* [63]	30.50 (27.992–33.01)		50.00 (47.38–52.62)		50.00 (47.38–52.62)	50.00 (47.38–52.62)
Tilahun *et al* [9]	60.80 (57.16–64.44)		45.00 (41.36–48.64)	45.20 (42.35–48.05)	47.80 (44.16–51.44)	41.30 (37.66–44.94)
Tilahun *et al* [64]	35.50 (32.65–38.35)				51.60 (48.75–54.45)	41.90 (39.05–44.75)
Regasa, *et al* [65]	20.00 (15.524- 24.48)		20.00 (15.52–24.48)			
Adugna, *et al* [66]	66.70 (5.78–67.62)					
Adhanom *et al* [67]	25.00 (23.45–26.55)		25.00 (23.45–26.55)			25.00 (23.45–26.55)
Genetu *et al* [68]	33.30 (29.80–36.80)		66.70 (63.20–70.20)		66.70 (63.20–70.20)	66.70 (63.20–70.20)
Worku *et al* [69]	26.30 (24.34–28.26)	85.00 (83.04–86.96)	66.70 (64.74–68.66)	66.70 (64.74–68.66)	68.40 (66.44–70.36)	5.30 (3.34–7.26)
Legese *et al* [70]	15.80 (14.74–16.86)				15.80 (14.74–16.86)	5.30 (4.24- 6.36)
Birru *et al* [71]	50.00 (48.77–51.23)				50.00 (48.77–51.23)	
Tadesse *et al* [45]	80.00 (77.32–82.68)	95.00 (92.32–97.68)	100.00 (97.32–102.68)	100.00 (97.32–102.68)	80.00 (77.32–82.68)	60.00 (57.32–62.68)

Table 4 (continued)

Teweldmedhin et al [72]	80.00 (76.49–83.51)	100.00 (96.49–103.51)	100.00 (96.49–103.51)	100.00 (96.45–103.51)	80.00 (76.49–83.51)	60.00 (56.49–63.51)
Motbainor *et al* [73]	36.40 (32.88–39.92)	100.00 (96.48–103.52)	100.00 (96.48–103.52)	100.00 (96.48–103.52)	63.60 (60.08–67.12)	45.50 (41.98–49.02)
Assefa *et al* [74]	33.30 (26.83–39.77)	33.30 (26.83–39.77)	33.30 (26.83–39.77)	33.30 (26.83–39.77)	33.30 (26.83–39.77)	
Ejerssa, *et al* [75]	50.00 (48.62–51.38)	100.00 (98.62–101.38)	100.00 (98.62–101.38)	100.00 (98.62–101.38)	50.00 (48.62–51.38)	
Mulu *et al* [76]	35.30 (33.49–37.16)		35.30 (33.49–37.12)		35.30 (33.49–37.12)	35.30 (33.49–37.12)
Belayhun *et al* [77]	50.00 (46.62–53.38)	21.40 (18.02–24.78)	64.30 (60.92–67.68)	64.30 (60.92–67.68)	21.40 (18.02–24.78)	28.60 (25.22–31.98)
Wasihun *et al* [78]	37.00 (31.26–42.74)	100.00 (94.26–105.74)	62.30 (56.56- 68.04)	100.00 (94.26–105.74)	80.00 (74.26–85.74)	60.00 (54.26–65.74)
Sewunet *et al* [79]	32.40 (30.84–33.96)	82.90 (81.63–84.17)	66.60 (65.04–68.16)		66.60 (65.04–68.16	66.60 (65.04–68.16)
Tekele *et al* [80]	17.60 (14.78–20.44)				23.50 (20.66–26.34)	5.90 (3.06–8.74)
Mekonnen *et al* [81]	61.10 (56.91–65.29)		50.00 (45.81–54.19)	50.00 (45.81–54.19)	83.30 (79.11–87.49)	16.70 (12.51–20.89)
Hailemariam *et al* [82]	68.60 (67.33–69.87)		37.10 (35.83–38.37)	60.00 (58.73–61.27)	17.00 (15.73–18.27)	8.60 (7.33–9.87)
Kefeni *et al* [83]	66.70 (63.79–69.61)	100.00 (97.09–102.91)	66.70 (63.79–69.61)	66.70 (63.79–69.61)	33.30 (30.39–36.21)	33.30 (30.39–36.21)
Awoke *et al* [84]	66.70 (64.35- 69.05)	100.00 (97.65–102.35)	66.70 (64.350–69.05)	66.70 (64.35–69.05)	66.70 (64.35–69.05)	66.70 (64.35–69.05)
Abdeta *et al* [85]	21.90 (20.43–23.37)		21.90 (20.43–23.37)	21.90 (20.43–23.37)	14.30 (12.83–15.77)	19.40 (17.93–20.87)
Addis *et al* [86]	43.00 (42.14–43.86)	100.00 (99.14–100.86)	21.90 (21.04–22.76)	21.90 (21.04–22.76)	14.30 (13.44–15.16)	25.00 (24.14–25.86)
Mitiku *et al* [87]	50.00 (48.18–51.8)	75.00 (73.18–76.82)	25.05 (23.18–26.82)	25.00 (23.18–26.82)	50.00 (48.18–51.82)	25.00 (23.18–26.82)
Seid *et al* [88]	33.30 (27.98–38.62)	33.30 (27.98–38.62)	33.30 (27.98–38.62)	33.30 (27.98–38.62)	33.30 (27.98–38.62)	66.60 (61.28–71.92)
Oumer *et al* [89]	33.30 (31.16–35.45)	33.30 (31.16–35.45)	33.30 (31.16–35.45)	33.30 (31.16–35.45)	33.30 (31.16–35.45)	66.70 (64.56–68.84)
Guteta *et al* [90]	39.40 (34.77–44.03)	100.00 (95.40–104.63)	66.70 (62.07–71.33)	66.70 (62.07–71.33)	36.40 (31.77–41.03)	60.60 (55.97–65.23)
Gebremedhin *et al* [91]	30.00 (27.94–32.06)	100.00 (97.94–102.06)	60.00 (57.94–62.06)	100.00 (97.94–102.06)	60.00 (57.94–62.06)	60.00 (57.94–62.06)
Abate et al [92]	75.00 (71.37–78.63)	100.00 (96.37–103.63)	91.60 (87.97–95.23)	91.60 (87.97–95.23)	41.70 (38.07–45.33)	41.60 (37.97–45.23)
Overall	**37.66 (32.94–42.38)**	**84.01 (76.66–91.35)**	**57.30 (50.301–64.30)**	**62.42 (53.11–71.73)**	**52.60 (44.29–60.90)**	**37.55 (32.03–43.07)**
I^2 (%)	**99.8%**	**99.7%**	**99.9%**	**99.9%**	**99.9%**	**99.8%**
***P*value**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**

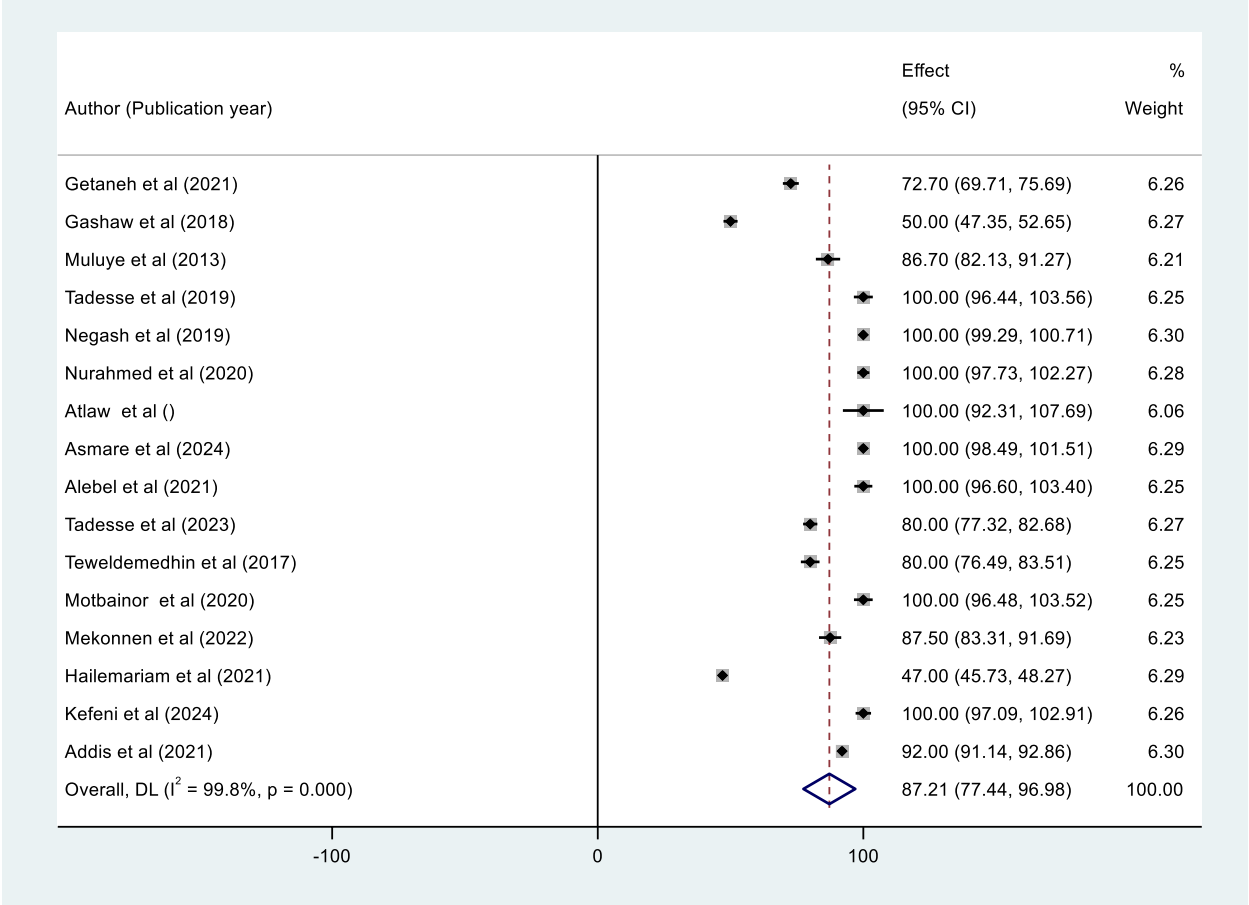

Fig. 2 Forest plot indicated that pooled AMC resistance of Acinetobacter species

62.42% (95% CI: 53.11–71.73), ceftazidime 52.60% (95% CI: 44.29–60.90), and meropenem 37.55% (95% CI: 32.03–43.07) (Table 4).

For *Acinetobacter* species, the resistance rates were: amoxicillin-clavulanic acid 87.21% (95% CI: 77.44–96.98), tetracycline 87.21% (95% CI: 77.44–96.98), amikacin 44.15% (95% CI: 32.75–55.54), gentamicin 58.90% (95% CI: 50.27–67.54), chloramphenicol 73.25% (95% CI: 58.29–88.21), SXT 75.33% (95% CI: 65.82–84.84), ciprofloxacin 54.73% (95% CI: 44.37–65.09), ceftriaxone 79.72% (95% CI: 69.36–90.10), cefotaxime 76.35% (95% CI: 67.32–85.38), ceftazidime 70.09% (95% CI: 62.64–77.55), and meropenem 44.40% (95% CI: 36.53–52.28) (Figs. 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12).

The pooled prevalence of MDR *Pseudomonas* and *Acinetobacter*

The magnitude of MDR *Pseudomonas* species in individual studies from Ethiopia varied from 27.80% to 100%. The overall pooled prevalence of MDR *Pseudomonas* isolated from clinical samples was 74.79% (95% CI: 70.14–79.43), with significant heterogeneity (I^2 = 99.7%, p < 0.001) across the studies. For *Acinetobacter* species, the prevalence of MDR varied from 33.3% to 100% in individual studies. The overall pooled prevalence of MDR Acinetobacter isolated from clinical samples was 84.69% (95% CI: 78.78–90.59), also showing high heterogeneity (I^2 = 99.7%, p < 0.001). Overall, the pooled prevalence of MDR for both species isolated from clinical samples in Ethiopia was 72.73% (95% CI: 67.02–78.44), exhibiting a high level of heterogeneity (I^2 = 99.8%, p < 0.001) across the studies (Table 5).

Subgroup analysis of MDR

The subgroup analysis demonstrated significant variations in the pooled prevalence of multidrug resistance (MDR) among *Pseudomonas* and *Acinetobacter* species across clinical sample types, geographic regions, study populations, and research characteristics. The overall pooled MDR prevalence from 65 studies was 72.73%

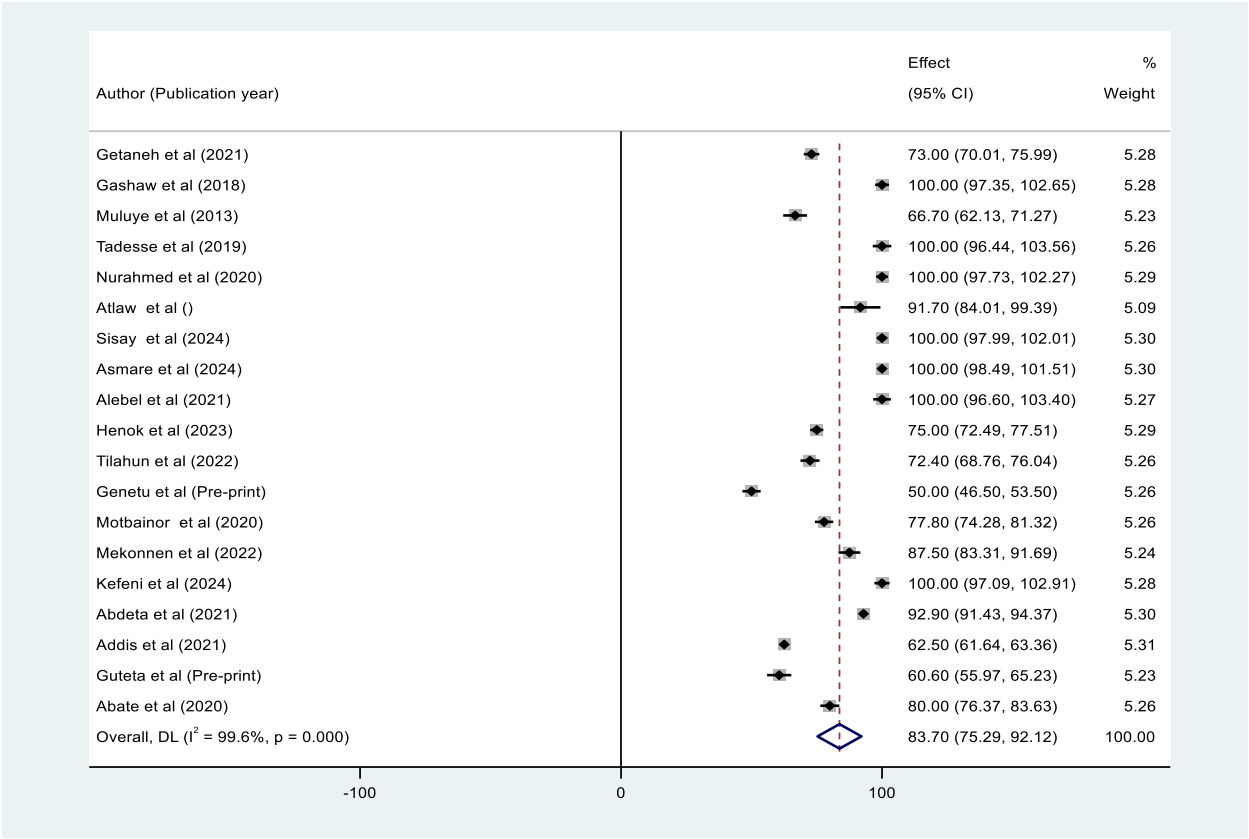

Fig. 3 Forest plot indicated that pooled TE resistance of Acinetobacter species

(95% CI: 67.02–78.44), with significant heterogeneity ($I^2 = 99.8\%$, $p < 0.001$). Among sample types, the highest MDR prevalence was observed in isolates from clean-catch midstream urine (80.19%, 95% CI: 69.38–90.99, $p < 0.001$), followed by pus aspirates and wound swabs (78.08%, 95% CI: 53.34–102.80, $p < 0.001$), general clinical samples (77.63%, 95% CI: 65.94–89.32, $p < 0.001$), and ear discharge (75.41%, 95% CI: 68.42–82.40, $p < 0.001$). In contrast, lower MDR prevalence was observed in sputum (62.64%, 95% CI: 46.00–78.85, $p < 0.001$), blood samples (48.73%, 95% CI: 46.28–51.18, $p < 0.001$), and ascitic fluid (50.0%, 95% CI: 47.38–52.62, single study). The difference in MDR prevalence among sample categories was statistically significant ($p < 0.001$).

Regional subgroup analysis revealed that the Harari region had the highest MDR prevalence at 85.86% (95% CI: 61.10–110.64, $p = 0.003$), although this was based on only three studies. This was followed by Amhara (78.31%, 95% CI: 71.39–85.24, $p < 0.001$) and Tigray (72.52%, 95% CI: 33.78–111.27, $p < 0.001$). The lowest MDR prevalence was reported from studies conducted in different parts of Ethiopia (60.64%, 95% CI: 34.86–86.41, $p = 0.001$) and in the Southern Nations, Nationalities, and Peoples'Region (SNNPR) (62.72%, 95% CI: 50.27–75.18, $p = 0.007$). The geographic differences were statistically significant ($p < 0.001$).

When stratified by publication year, studies published in or after 2021 reported a higher pooled MDR prevalence (76.57%, 95% CI: 67.99–85.20, $p < 0.001$) compared to those published before 2021 (69.30%, 95% CI: 61.83–76.63, $p < 0.001$), though the difference between the two periods was not statistically significant ($p = 0.204$).

Regarding study populations, studies including all age groups showed the highest MDR prevalence (73.83%, 95% CI: 66.83–80.85, $p = 0.003$), followed by those focusing on children under 15 years (69.03%, 95% CI: 58.83–79.23, $p < 0.001$) and adult patients (63.54%, 95% CI: 31.64–95.45, $p < 0.001$). The variation among these

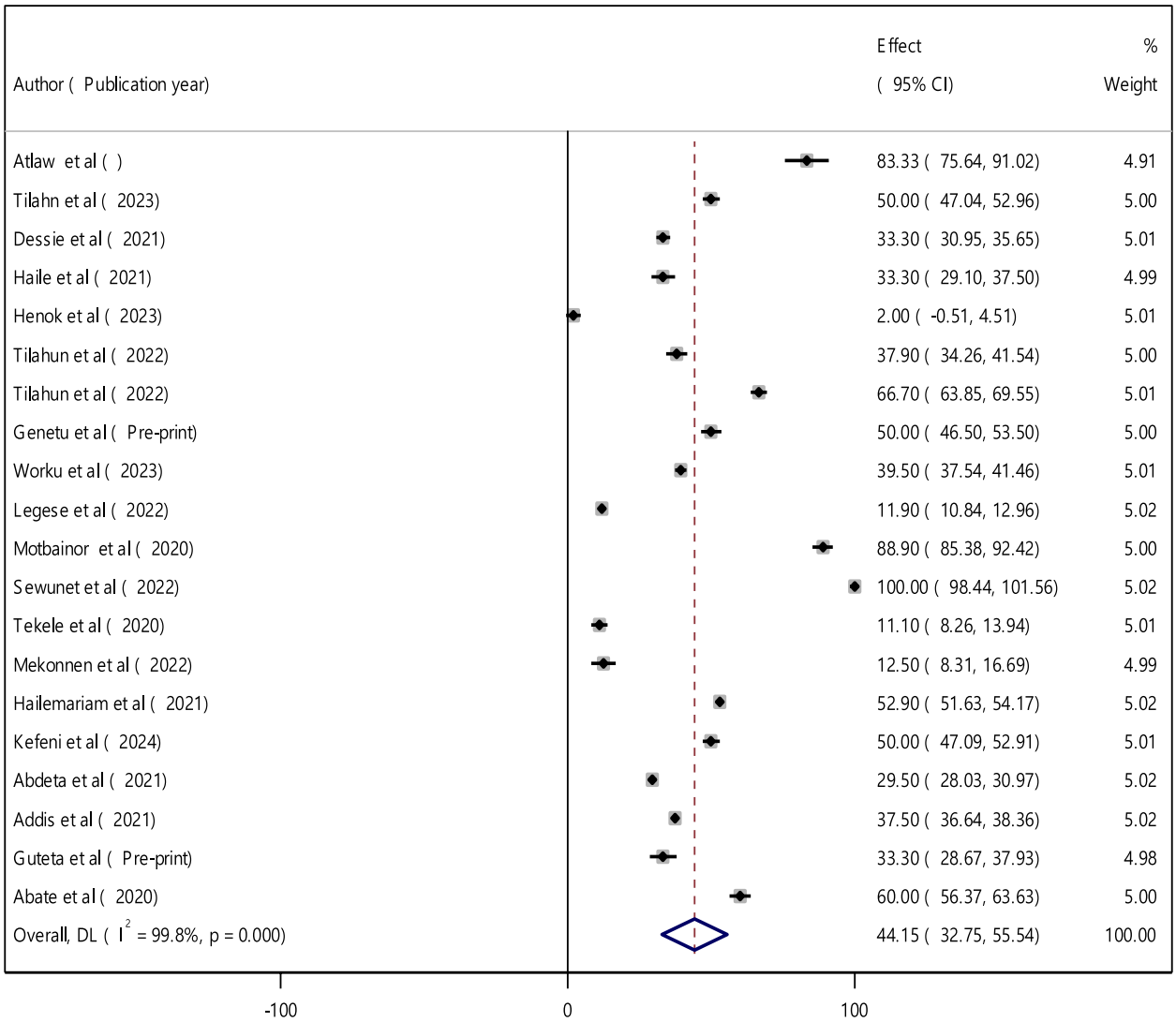

Fig. 4 Forest plot indicated that pooled AMK resistance of Acinetobacter species

groups was statistically significant ($p < 0.001$), suggesting age may influence MDR patterns.

No significant difference was observed based on study sample size. Studies with fewer than 300 participants reported a pooled MDR prevalence of 72.35% (95% CI: 64.19–80.52, $p < 0.001$), while those with 300 or more reported 73.23% (95% CI: 64.26–82.20, $p < 0.001$); the difference between groups was not statistically significant ($p = 0.800$). Overall, the findings indicate a high prevalence of MDR among *Pseudomonas* and *Acinetobacter* species in Ethiopia, with statistically significant variation by sample type, region, and patient population (Table 6).

Sensitivity analysis

According to the sensitivity analysis results, no individual study had a significant effect on the pooled estimate of prevalence, indicating a consistent overall outcome. When each study was excluded, the pooled effect size remained within the 95% confidence interval of the total pooled effect size. This demonstrates that no single study had a substantial impact on the overall prevalence of *Pseudomonas* and *Acinetobacter* species infections among children in Ethiopia (Table 7).

Publication bias

The funnel plot was used to assess the impact of the small studies effect or publication bias on the estimated pooled prevalence. The graph of the funnel plot looks asymmetrical indicating the presence of publication bias (Fig. 13).

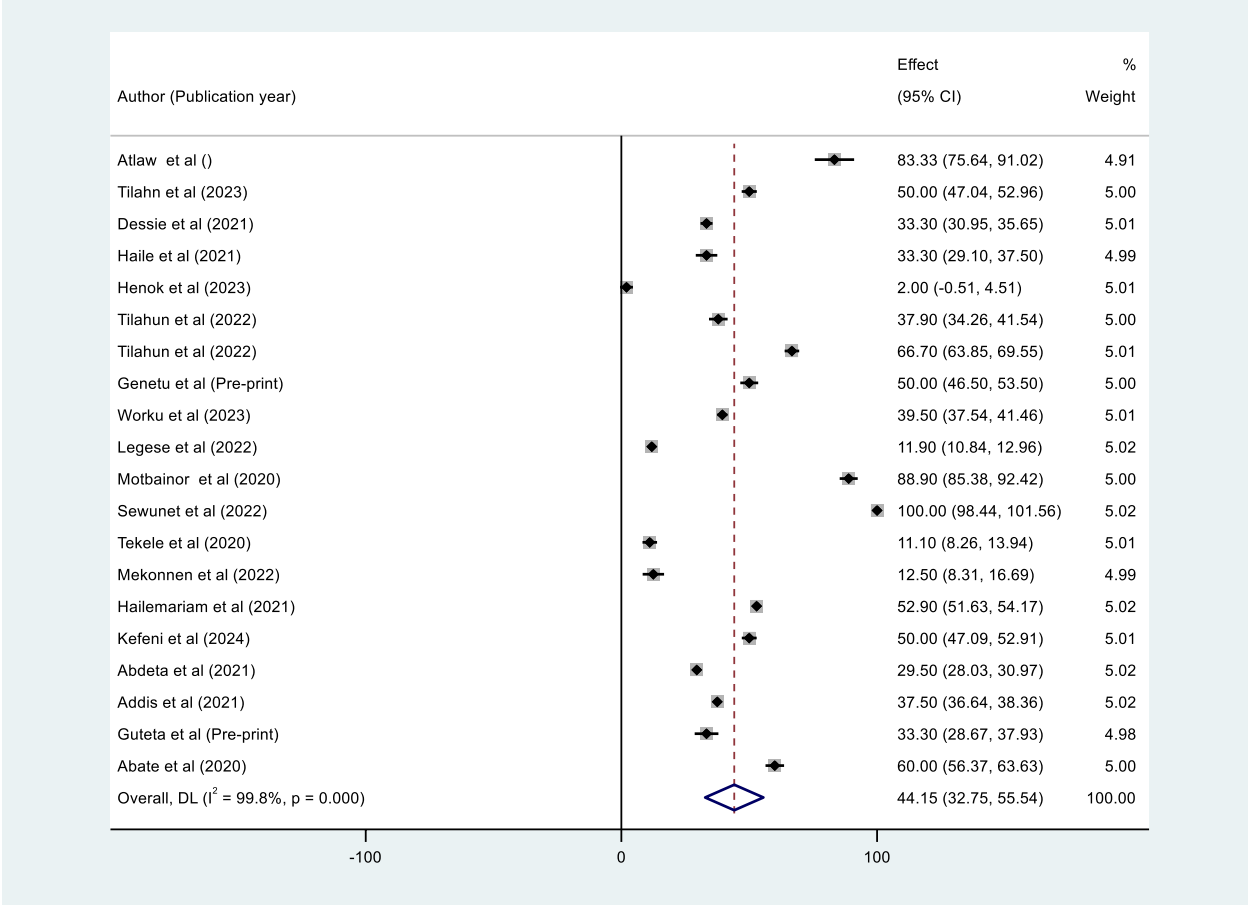

Fig. 5 Forest plot indicated that pooled GM resistance of Acinetobacter species

Thus, an egger's test statistics confirmed the presence of publication bias at a *P*-value of < 0.05 (Table 8 and Fig. 14).

Trim and fill analysis of the pooled prevalence of *Pseudomonas and Acinetobacter species* in Ethiopia

A trim and fill analysis were performed due to the presence of publication bias. After adding 20 studies, the pooled prevalence of *Pseudomonas and Acinetobacter species* among children in Ethiopia was 2.544% (95% CI: 1.506–3.581) (Table 9).

Meta-regression

Meta-regression has been conducted that characterizes the predictions for the pooled prevalence of *Pseudomonas and Acinetobacter species* infections among children due to sample size increment, and variables variation between studies. In this study, sample size was responsible variables for the existence of heterogeneity between studies ($P < 0.05$) (Table 10).

Discussion

Reports indicated increasing rates of antimicrobial resistance in *Pseudomonas* species and *Acinetobacter* species Globally and in Ethiopia, high rates of antibiotic resistance have been reported among *Pseudomonas* and *Acinetobacter* species. These pathogens are increasingly associated with multidrug-resistant infections, particularly in hospital settings [93, 94]. Their resistance to multiple antibiotic classes, including β-lactams and fluoroquinolones, poses a serious challenge to treatment and highlights the urgent need for enhanced antimicrobial stewardship and infection control efforts [95]. The pooled prevalence of *Pseudomonas* and *Acinetobacter* species in Ethiopia was 19.12% (95% CI: 14.86–23.38) and 12.46% (95% CI: 5.82–19.10), respectively. The combined pooled prevalence for both pathogens was 25.31%

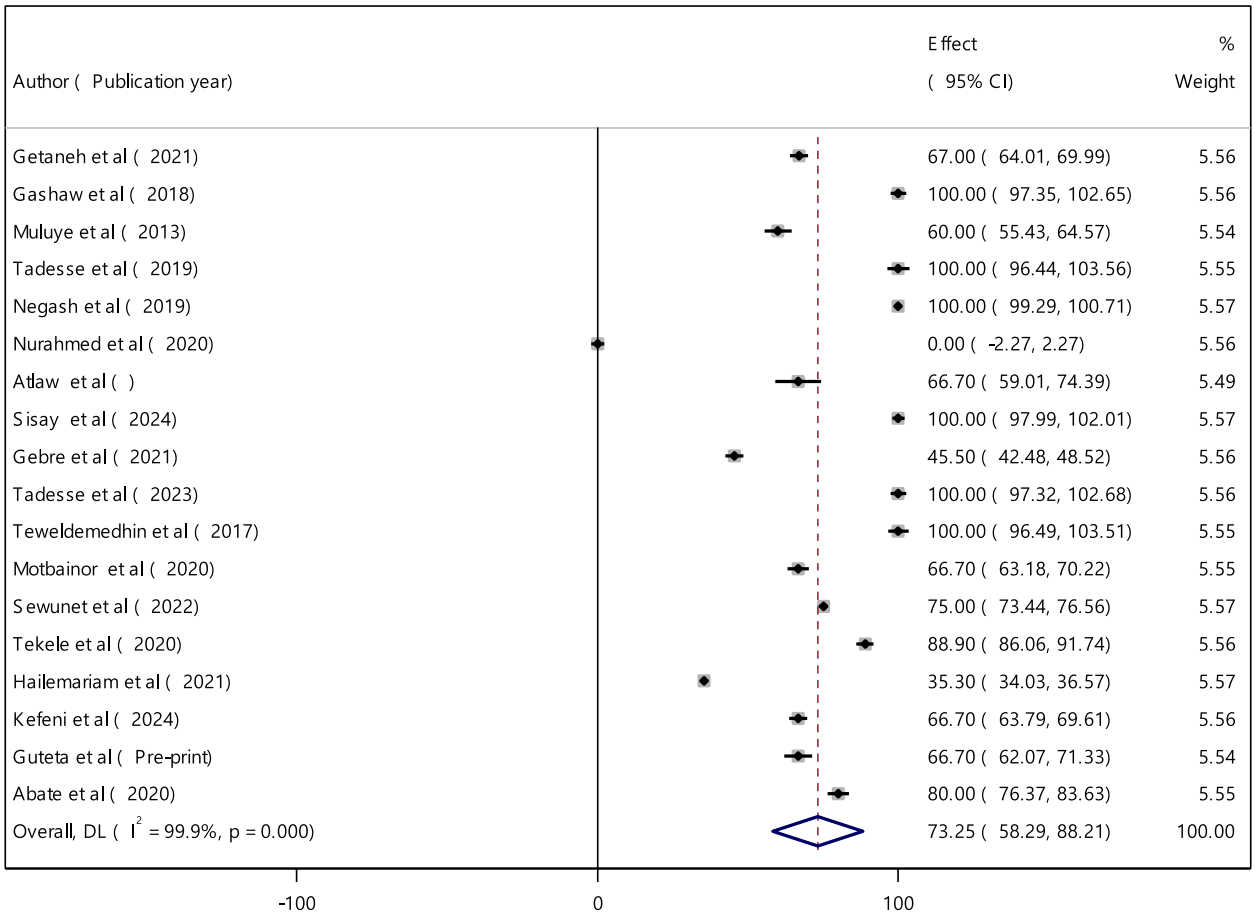

Fig. 6 Forest plot indicated that pooled C resistance of Acinetobacter species

(95% CI: 18.61–32.00), with high heterogeneity among the studies (I2 = 93.6%, $p < 0.001$). This prevalence in line with the reported rate from Egypt (19.9%) [96]. Globally, *Pseudomonas* and *Acinetobacter* species often have lower reported prevalence rates in regions like North America and Europe, typically ranging from 10 to 15% for *Pseudomonas* and 5% to 10% for *Acinetobacter* [97]. Review done in Ethiopia on *P. aeruginosa* was reported 4.38% [12] and reported from China was (6.53%) [98]. The possible contributing factors to increased prevalence in Ethiopia might be the abuse of antibiotics without a prescription, inadequate infection control procedures, and healthcare infrastructure issues [5, 12]. The high frequency of these infections poses major public health risks, particularly for vulnerable groups in healthcare settings, resulting in higher morbidity and healthcare costs.

The high pooled incidence of *Pseudomonas* (19.12%) and *Acinetobacter* (12.46%) species in Ethiopia raises serious public health concerns. Comparing these findings with neighbouring Kenya, which reports a pooled prevalence of *Pseudomonas* species between 15–25% and Acinetobacter between 10–20% [99], highlights regional variability. In contrast, a study in Nigeria found *Pseudomonas* prevalence at around 10% [100], and a meta-analysis in India reported Acinetobacter at approximately 7% [101]. These discrepancies likely reflect differences in healthcare practices, antibiotic usage, and environmental conditions. Alarmingly, some Middle Eastern countries report even higher rates of antibiotic resistance among these pathogens, emphasizing the global nature of this public health issue.

A systematic review from Saudi Arabia reported that over 80% of *Pseudomonas* isolates were resistant to multiple drug classes [102]. In this systematic review and meta-analysis, the pooled resistance profiles for *Pseudomonas* species in Ethiopia reveal alarmingly high rates of antimicrobial resistance. The resistance rate for amoxicillin-clavulanic acid was found to be 83.73% (95%

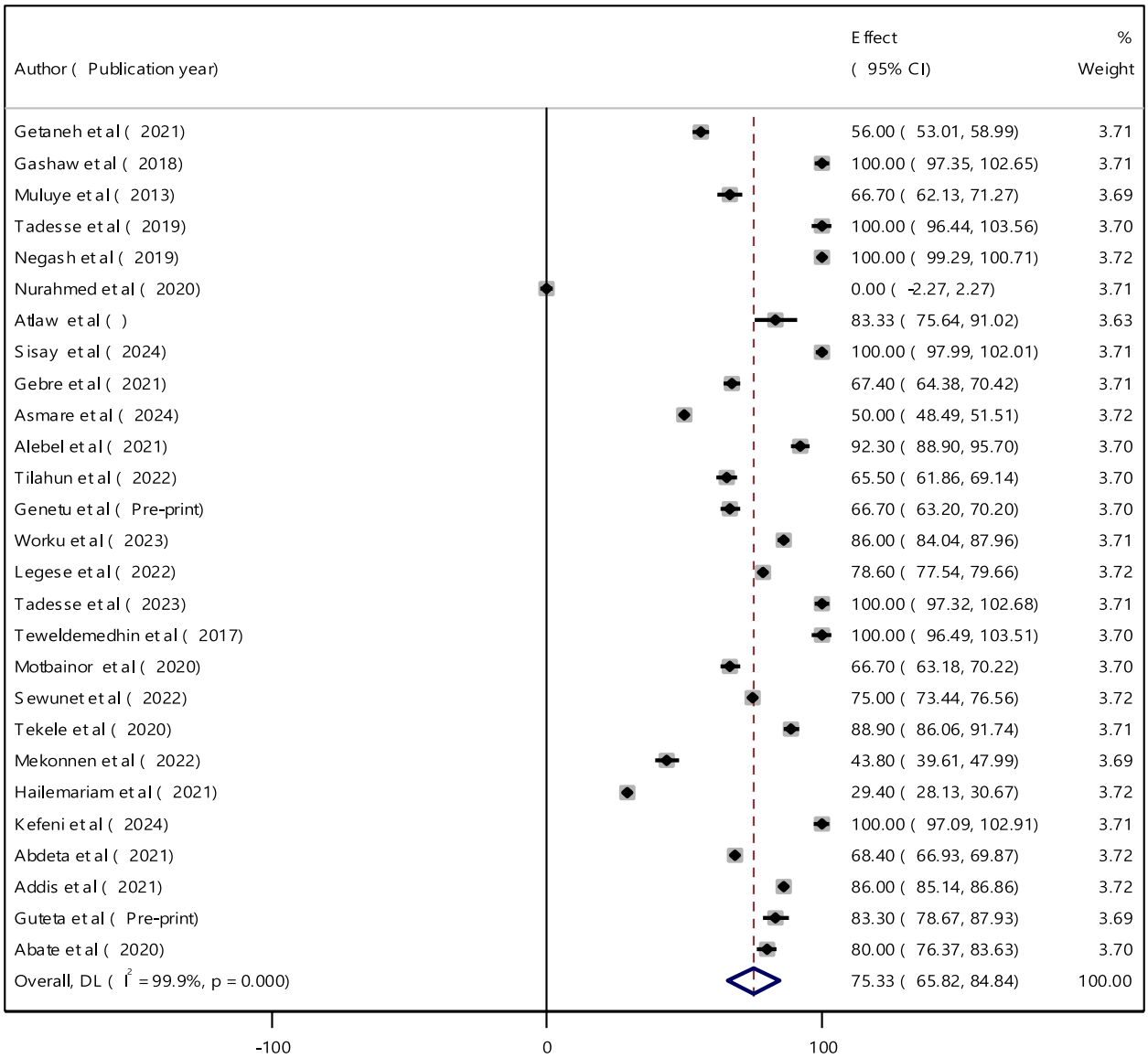

Fig. 7 Forest plot indicated that pooled SXT resistance of Acinetobacter species

CI: 78.79–88.67), indicating that this combination antibiotic is largely ineffective against *Pseudomonas* infections in the country. Tetracycline showed an even higher resistance rate of 89.15% (95% CI: 82.17–108.12), posing significant treatment challenges for infections typically managed with this antibiotic. Amikacin resistance was noted at 37.74% (95% CI: 30.21–45.27), which, while lower than other antibiotics, still indicates a substantial level of resistance that could impact treatment efficacy. Gentamicin's resistance rate of 47.68% (95% CI: 39.16–56.20) suggests it may still be a viable option, albeit with caution due to notable resistance. Other antibiotics, such as chloramphenicol (58.69%), sulfamethoxazole-trimethoprim (65.58%), and ciprofloxacin (37.66%), also show concerning resistance levels. Alarmingly, ampicillin resistance reached 84.01% (95% CI: 76.66–91.35), highlighting its ineffectiveness, while ceftriaxone resistance was found at 57.30% (95% CI: 50.30–64.30), raising concerns for treating severe infections. Ceftazidime and cefotaxime also exhibited high resistance rates of 52.60% (95% CI: 44.29–60.90) and 62.42% (95% CI: 53.11–71.73), respectively. Meropenem, a last-resort antibiotic, showed

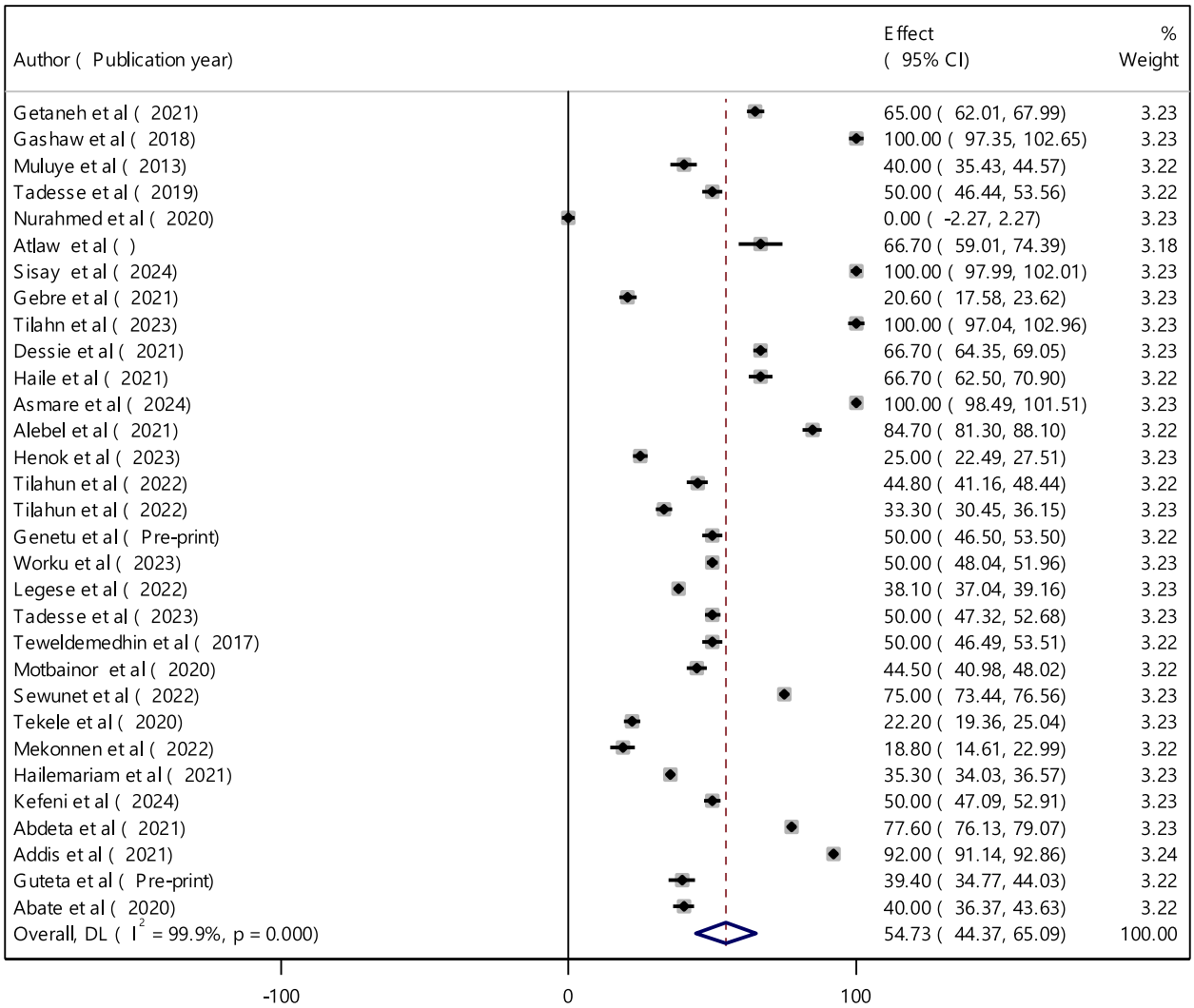

Fig. 8 Forest plot indicated that pooled SXT resistance of Acinetobacter species

a resistance rate of 37.55% (95% CI: 32.03–43.07), indicating it may still be effective but requires careful consideration. In comparison of systematic review and meta-analysis examined the antimicrobial resistance (AMR) profiles of Pseudomonas aeruginosa for ten antibiotics.

The pooled prevalence of AMR varied significantly among the antibiotics studied. Resistance rates ranged from 20.9% (95% CI: 6.2–35.8) for amikacin to a concerning 98.72% (95% CI: 96.39–101.4) for ceftriaxone. Specifically, the resistance to third-generation cephalosporins was notably high, with 66.8% for ceftazidime and the highest rate of 98.72% for ceftriaxone. In contrast, relatively lower resistance levels were observed for amikacin and meropenem, the latter showing a resistance rate of 28.64% (95% CI: 16.35–40.93). These findings underscore significant challenges in treating *P. aeruginosa* infections in the studied population, highlighting the need for improved antimicrobial stewardship [12].

Turkey's The pooled resistance prevalence of *P. aeruginosa* is as follows: piperacillin-tazobactam (33.9%), ceftazidime (38.6%), cefepime (35.6%), meropenem (30.1%), imipenem (28.0%), ciprofloxacin (30.7%), gentamicin (28.2%), amikacin (17.8%), tobramycin (15.7%), and colistin (2.2%) [96]. In China, the overall proportion of *P. aeruginosa* antibiotic resistance rates has shown a significant increase since 2015. Specifically, resistance rates for cefoperazone reached 36.2%, ceftriaxone 38.9%, levofloxacin 20.5%, and aztreonam 24.0%. Alarmingly, resistance to ampicillin and cefazolin has exceeded 90.0% [103].

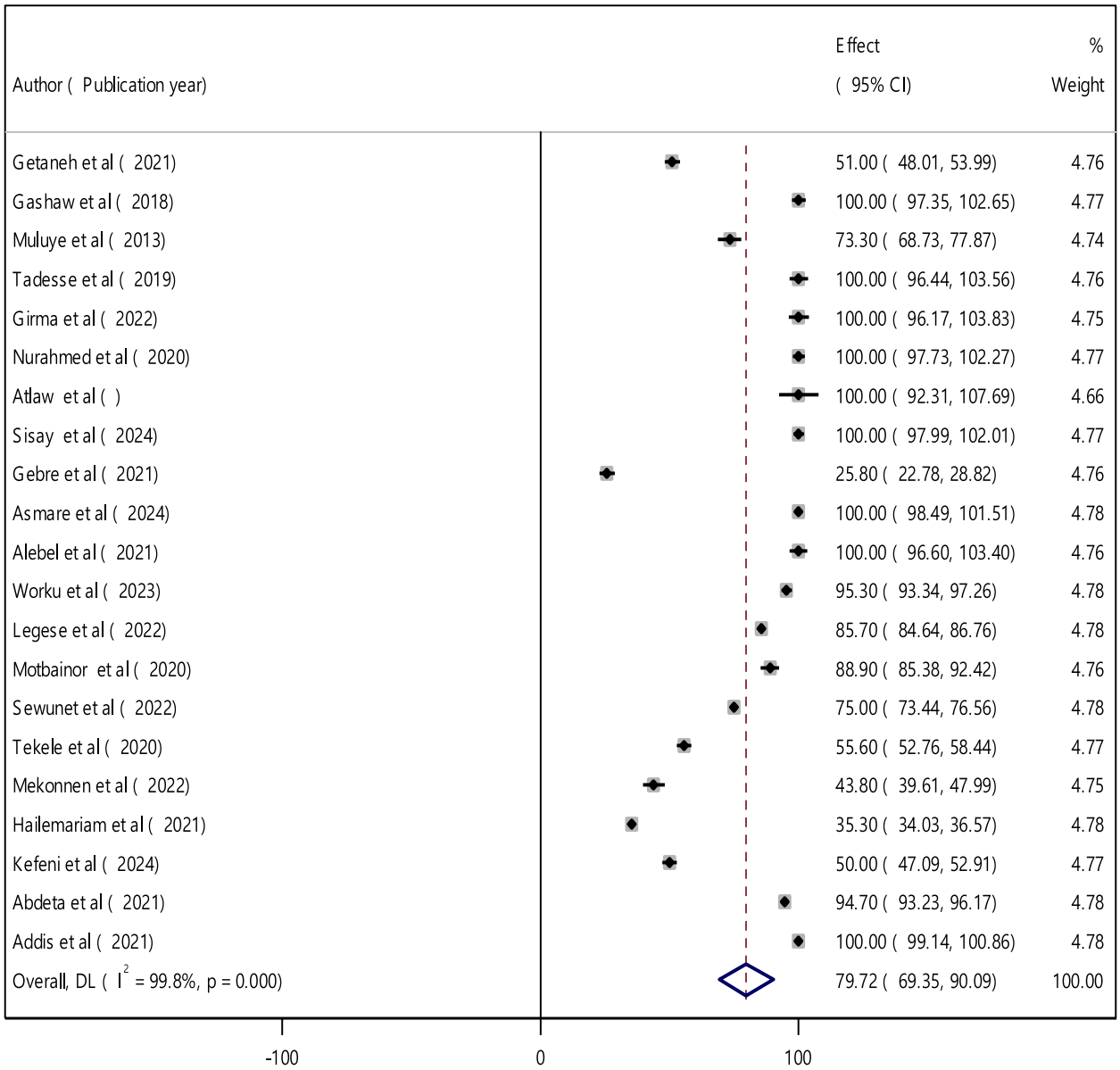

Fig. 9 Forest plot indicated that pooled CRO resistance of Acinetobacter species

The antimicrobial resistance (AMR) rates for *Acinetobacter* species are alarmingly high, with resistance to amoxicillin-clavulanic acid and tetracycline at 87.21% each, ceftriaxone at 79.72%, and gentamicin at 58.90%. These rates significantly exceed those reported globally, such as 60.0% for amoxicillin-clavulanic acid in Turkey [104] and 30.0% for gentamicin in Brazil [105]. Moreover, meropenem resistance in Ethiopia is 44.40%, much higher than the 10–20% seen in Europe [106]. Similarly, Middle Eastern studies indicated Acinetobacter resistance rates of 60–75% for amoxicillin-clavulanic acid, again lower than Ethiopia's findings (Oduor et al., 2020). High antimicrobial resistance in Ethiopia stems from factors like the overuse and misuse of antibiotics, often due to lax regulations and easy access without prescriptions. This poses a serious public health challenge, particularly for vulnerable populations at risk for nosocomial infections. Extended hospital stays due to chronic illnesses further increase exposure to multidrug-resistant organisms. The severe implications for immunocompromised patients

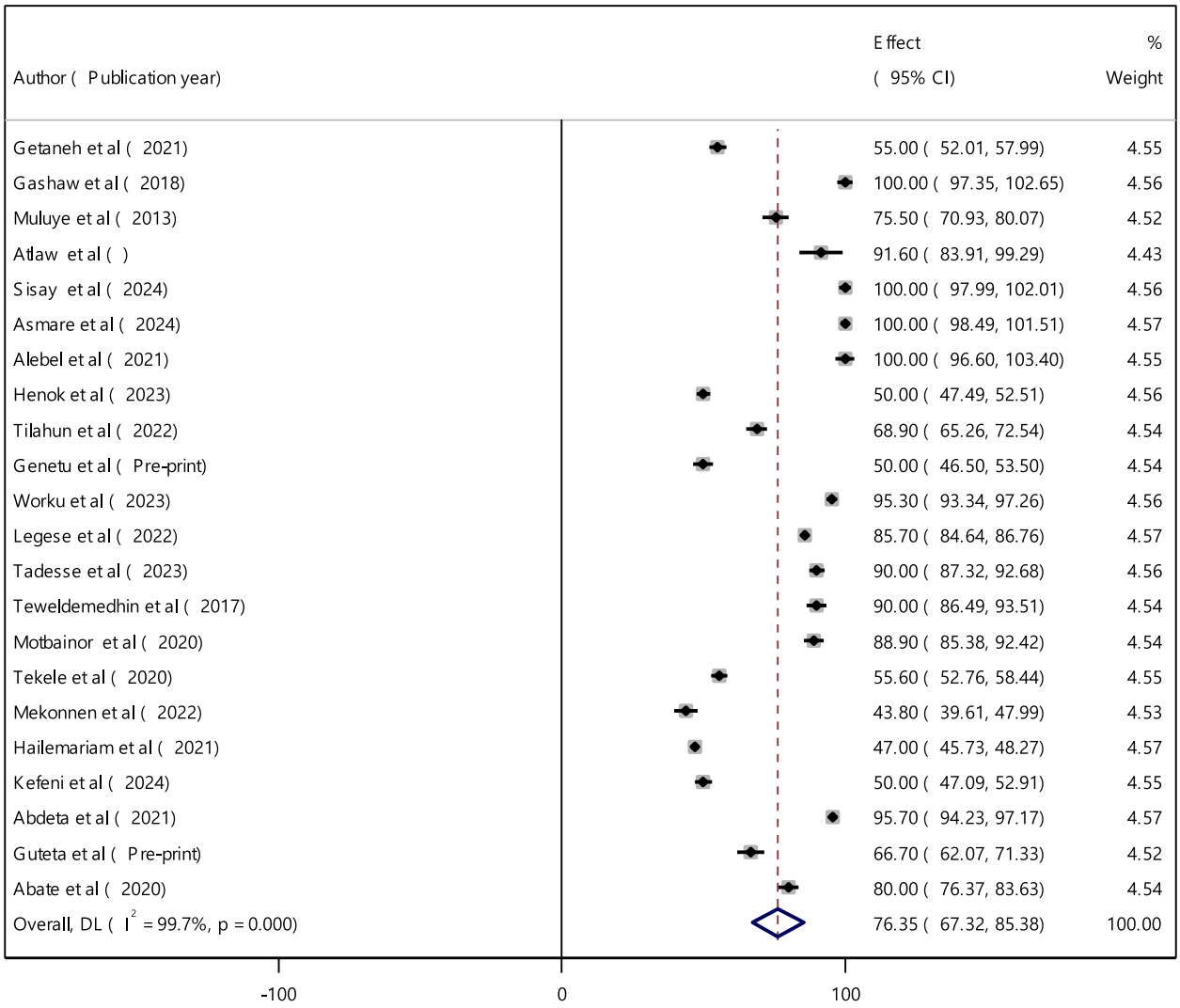

Fig. 10 Forest plot indicated that pooled CXT resistance of Acinetobacter species

necessitate urgent interventions, including better antibiotic stewardship and infection control.

Multidrug-resistant (MDR) pathogens were defined according to the international consensus guidelines proposed as those non-susceptible to at least one agent in three or more antimicrobial categories [107]. This definition was consistently applied across all included studies. The emergence of multidrug-resistant (MDR) *Pseudomonas* and *Acinetobacter* species in Ethiopia represents a significant public health challenge, with individual studies reporting MDR prevalence for *Pseudomonas* ranging from 27.80% to 100%. The overall pooled prevalence of MDR *Pseudomonas* isolated from clinical samples is 72.73% (95% CI: 67.02–78.44), exhibiting high heterogeneity (I2 =99.8%, $p <$ 0.001). Similarly, the prevalence of MDR Acinetobacter species varies from 33.3% to 100%, with a pooled prevalence of 84.69% (95% CI: 78.78–90.59), also demonstrating significant heterogeneity (I2 =99.7%, $p <$ 0.001). When considering both species, the overall pooled prevalence of MDR in Ethiopia is 74.79% (95% CI: 70.14–79.43), with a notable level of heterogeneity (I2 =99.7%, $p <$ 0.001 The multidrug-resistant (MDR) rates observed in Ethiopia align closely with those reported, a systematic review in Ethiopia reported MDR *Pseudomonas* rates around 80%, [12], from Somalia (68%) [108] and Nepal (83.3%) [109]. However, it surpasses the rate reported from India (50%) [110], Spain (26.2%) [111], and Iran (58%) [112]. While studies from Turkey indicated MDR Acinetobacter prevalence ranging from 60 to 80% [104]. Furthermore, a South African

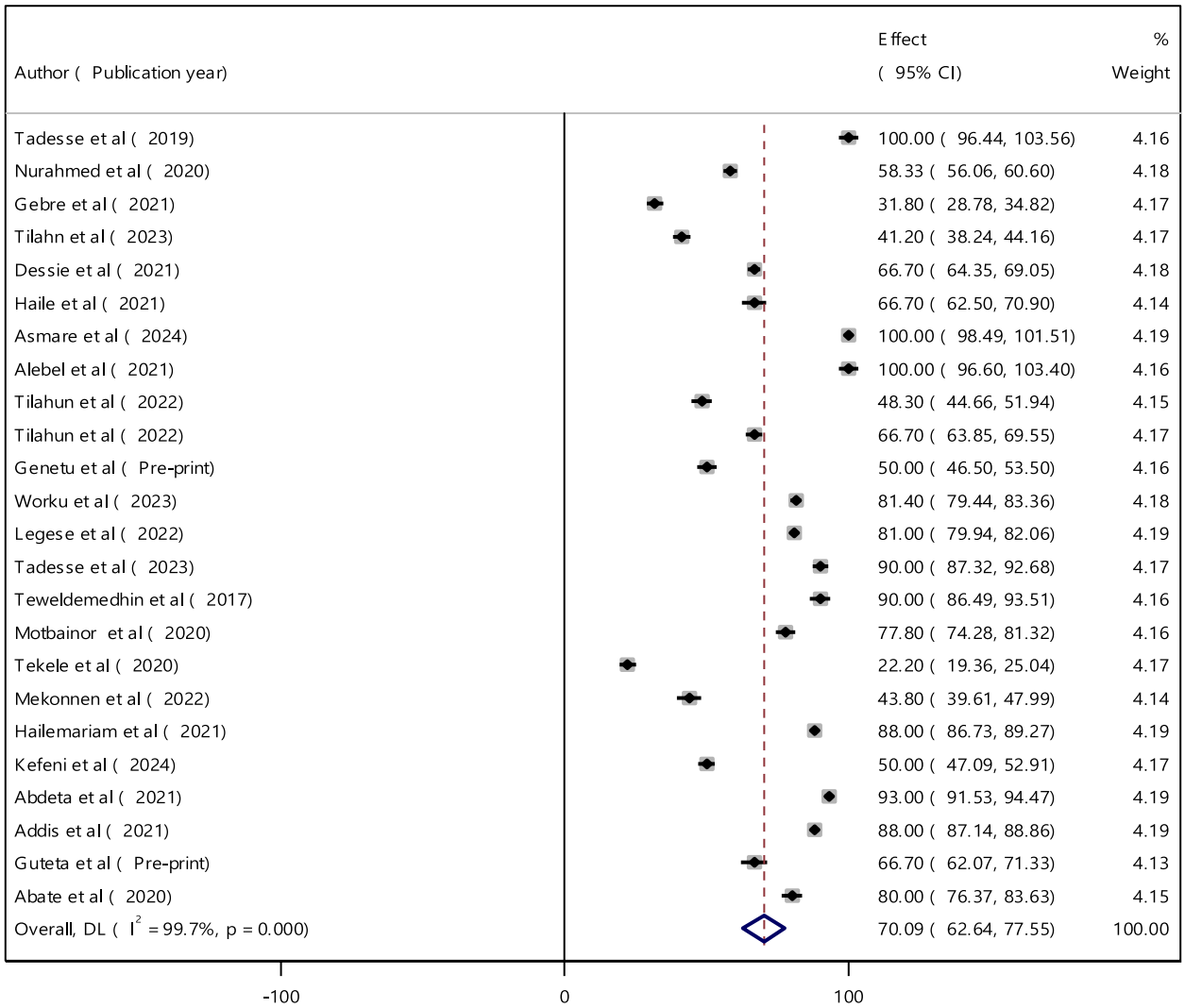

Fig. 11 Forest plot indicated that pooled CAZ resistance of Acinetobacter species

study reported MDR prevalence of 50% for *Pseudomonas* and 70% for *Acinetobacter* [113]. To address the high resistance rates, Ethiopia should prioritize the implementation of antibiotic stewardship programs, strengthen infection prevention and control measures, and enhance surveillance systems to monitor resistance patterns.

Subgroup analysis of *Pseudomonas* and *Acinetobacter* species in clinical samples from Ethiopia revealed significant variation in prevalence and multidrug resistance (MDR) across age groups, sample types, regions, and publication years. The overall prevalence was 7.78%, with higher rates in children and studies published before 2021. The Amhara region and ear discharge/wound samples showed the highest prevalence. MDR prevalence was alarmingly high at 72.73%, particularly in urine, pus, and ear discharge samples, with the Harari region showing the highest MDR levels. Differences by age and region were statistically significant, highlighting the need for targeted infection control and antimicrobial resistance strategies.

The sensitivity analysis's findings showed that no single study had a substantial impact on the combined estimate of the percentage of *Pseudomonas* and *Acinetobacter* species infections in Ethiopian. When every study was excluded out of the analysis, the pooled effect size was always within the overall estimate's 95% confidence interval. This stability suggests that the overall prevalence figures are robust and reliable, reinforcing

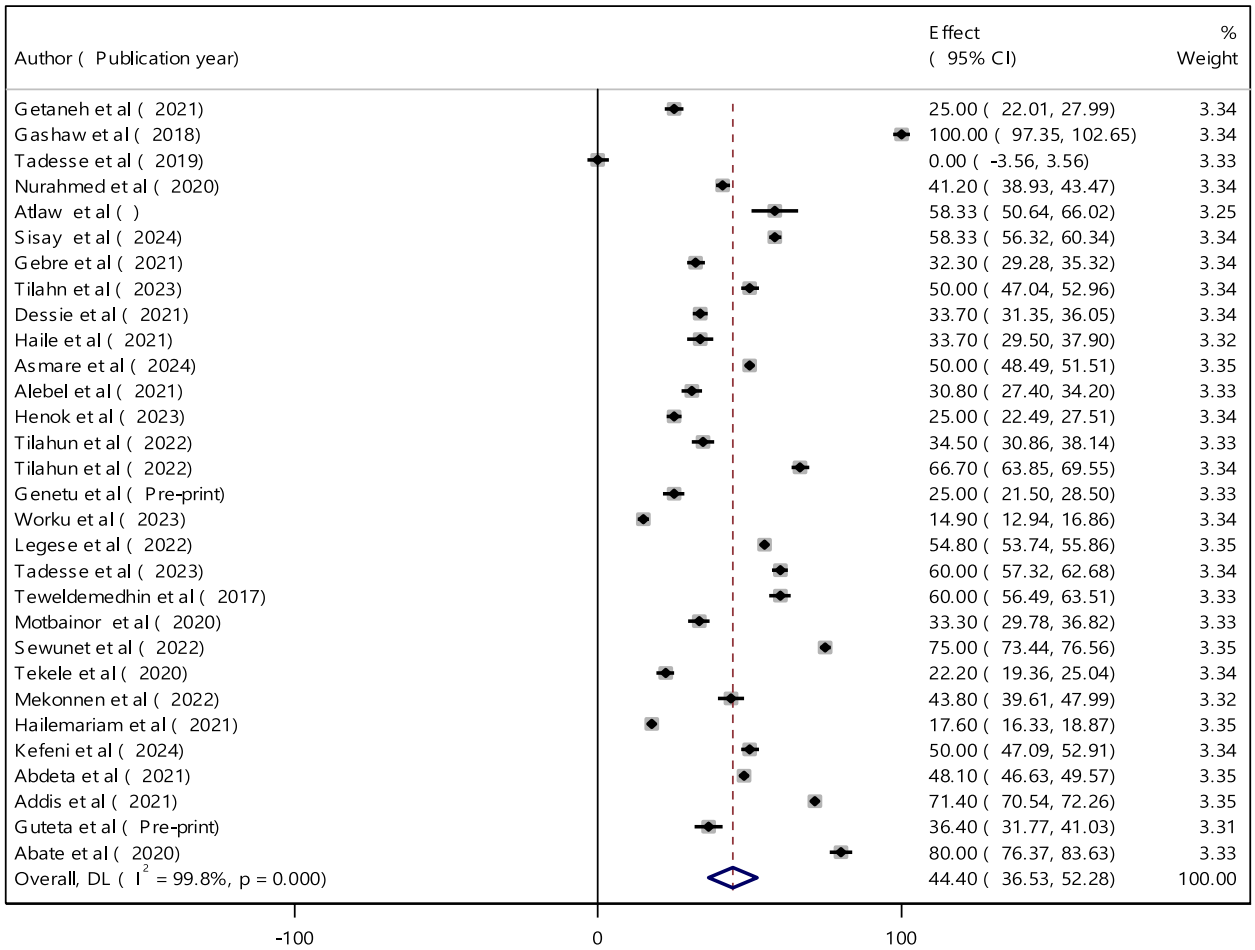

Fig. 12 Forest plot indicated that pooled MEM resistance of Acinetobacter species

the conclusion that the findings represent a true reflection of the situation, rather than being skewed by any particular study. Such consistency is crucial for informing public health strategies and interventions aimed at addressing these infections.

A trim and fill analysis were conducted to address the identified publication bias. The funnel plot used to assess the impact of small study effects appeared asymmetrical, indicating the presence of publication bias. This finding was corroborated by Egger's test, which confirmed significant publication bias with a *P*-value of less than 0.05. After incorporating 20 additional studies into the analysis, the revised pooled prevalence of Pseudomonas and Acinetobacter species infections among children in Ethiopia was determined to be 2.544% (95% CI: 1.506–3.581). These adjustments underscore the importance of accounting for publication bias to ensure more accurate prevalence estimates in the study of these infections.

The study is limited by the potential for publication bias, as only published studies were included. Additionally, the exclusion of grey literature may have resulted in an underestimation of the true prevalence and resistance rates.

Conclusion

This systematic review and meta-analysis reveal a significant burden of antimicrobial resistance among *P. aeruginosa* and *Acinetobacter species* in Ethiopia, with pooled prevalences of 19.12% and 12.46%, and a combined prevalence of 25.31%. Multidrug-resistant *Pseudomonas* and *Acinetobacter* species are highly prevalent in

Table 5 Pooled MDR of *Pseudomonas and Acinetobacter species* in Ethiopia

Author	Over all MDR Effect [95% CI]	*Acinetobacter species* MDR Effect [95% CI]	*Pseudomonas* spp. MDR Effect [95% CI]
Abera *et al* [30]	67.56 (65.13–9.99)		67.56 (65.13–9.99)
Dereje et al. [31]	75.00 (73.15–76.85)		75.00 (73.15–76.85)
Misha et al. [32]	87.50 (85.32–89.68)		87.50 (85.32–89.68)
Endaylalu et al. [33]	53.70 (48.34–59.06)		53.70 (48.34–59.06)
Getaneh et al. [34]	75.00 (72.01–77.99)	72.70 (69.71–75.69)	74.30 (71.31–77.29)
Gorems et al. [35]	78.90 (74.24–83.56)		78.90 (74.24–83.56)
Hailu et al. [36]	85.20 (80.84–89.56)	75.20 (70.84–79.56)	75.20 (70.84–9.56)
Gashaw et al. [37]	7.80 (5.15–10.45)	50.00 (7.35–52.65)	72.70 (70.05–75.35)
Chernet et al. [38]	75.00 (73.70–76.30)		75.00 (73.70–76.30)
Molla et al. [39]	100.00 (95.62–104.38)		100.00 (95.62–104.38)
Muluye et al. [40]	83.30 (78.73–87.87)	80.00 (75.43–84.57)	81.80 (77.23–86.37)
Muleta et al. [41]	55.60 (50.97–60.23)		55.60 (50.97–60.23)
Hailegiyorgis et al. [42]	54.50 (50.62- 58.38)		54.50 (50.62- 58.38)
Tolera et al. [43]	66.70 (65.49–67.91)		66.70 (65.49–67.91)
Seid et al. [44]	66.70 (61.54–71.86)		66.70 (61.54–71.86)
Tadesse et al. [45]	83.30 (79.74–86.86)	100.00 (96.44–103.56)	87.50 (83.94–91.06)
Girma et al. [46]	75.00 (71.17–78.83)		75.00 (71.17–78.83)
Negash [47]	66.70 (65.99–67.41)	100.00 (99.29–100.71)	75.00 (71.17–78.83)
Nurahmed et al. [48]	71.40 (69.13–3.67)	100.00 (97.73–102.27)	75.00 (74.29–75.71)
Hailu et al. [49]	55.50 (52.92–8.08)		55.50 (52.92–8.08)
Regassa et al. [50]	55.50 (51.64–59.36)		55.50 (51.64–59.36)
Atlaw et al. [51]	91.60 (83.91–99.29)	100.00 (92.31–107.69)	94.40 (86.71–102.09)
Sisay et al. [52]	66.70 (64.69–68.71)	100.00 (97.99–102.01)	68.80 (66.79–70.81)
Gebre et al. [53]	16.00 (12.98–19.02)	10.50 (7.48–13.52)	9.10 (6.08–12.12)
Temesgen et al. [54]	42.10 (40.08–44.12)		42.10 (40.08–44.12)
Tilahun et al. [55]	85.30 (82.34–88.26)	100.00 (97.04–102.96)	86.10 (83.14–89.06)
Dessie et al. [56]	95.50 (93.15–97.85)	100.00 (97.65–102.35)	52.00 (49.65–54.35)
Haile et al. [57]	90.90 (86.70–95.10)	100.00 (95.80–104.20)	52.00 (47.80–56.20)
Moges et al. [58]	100.00 (99.43–100.57)		100.00 (99.43–100.57)
Assefa et al. [59]	100.00 (98.61–101.39)		100.00 (98.61–101.39)
Asmare et al. [60]	100.00 (98.49–101.51)	100.00 (98.49–101.51)	100.00 (98.49–101.51)
Alebel et al. [61]	100.00 (96.60–103.40)	100.00 (96.60–103.40)	100.00 (96.60–103.40)
Henok et al. [62]	84.60 (82.09–87.11)	75.00 (72.49–77.51)	82.35 (79.84–84.86)
Alelign et al. [63]	50.00 (7.38–52.62)		50.00 (7.38–52.62)
Tilahun et al. [9]	84.80 (81.16–88.44)	89.70 (86.06–93.34)	86.70 (83.06–90.34)

Table 5 (continued)

Author	Over all MDR Effect [95% CI]	*Acinetobacter species* MDR Effect [95% CI]	*Pseudomonas* spp. MDR Effect [95% CI]
Tilahun et al. [64]	67.70 (64.85–70.55)	33.30 (30.45–36.15)	64.70 (61.85–67.55)
Regasa, et al. [65]	20.00 (15.52–24.48)		20.00 (15.52–24.48)
Adugna, et al. [66]	75.00 (74.08–75.92)		75.00 (74.08–75.92)
Adhanom et al. [67]	25.00 (23.45- 26.55)		25.00 (23.45- 26.55)
Genetu *et al.* [68]	66.70 (63.20–70.20)	66.70 (63.20–70.20)	66.70 (63.20–70.20)
Worku et al. [69]	73.80 (71.84–75.76)	93.00 (91.04–94.96)	87.10 (85.14–89.06)
Legese et al. [70]	47.50 (46.44–48.56)	83.40 (82.34–84.46)	72.10 (71.04–73.16)
Birru et al. [71]	50.00 (48.77–51.23)		50.00 (48.77–51.23)
Tadesse et al [45]	100.00 (97.32–102.68)	100.00 (97.32–102.68)	100.00 (97.32–102.68)
Teweldmedhin et al. [72]	100.00 (96.49–103.51)	100.00 (96.49–103.51)	100.00 (96.49–103.51)
Motbainor et al. [73]	100.00 (96.48–103.524)	100.00 (96.48–103.52)	100.00 (96.476 103.52)
Assefa et al. [74]	66.70 (60.23–73.17)		66.70 (60.23–73.17)
Ejerssa, et al. [75]	100.00 (98.62–101.38)		100.00 (98.62–101.38)
Mulu et al. [76]	73.30 (71.49–75.12)		73.30 (71.49–75.12)
Belayhun et al. [77]	50.00 (46.62–53.38)		50.00 (46.62–53.38)
Wasihun et al. [78]	85.20 (79.46–90.94)		85.20 (79.46–90.94)
Sewunet et al. [79]	83.40 (81.84–84.96)	76.90 (75.34–78.46)	81.30 (79.74–82.87)
Tekele et al. [80]	100.00 (97.16–102.84)	88.90 (86.06–91.74)	96.20 (93.36–99.04)
Mekonnen et al. [81]	83.30 (79.11–87.49)	83.30 (79.11–87.49)	82.40 (78.21–86.59)
Hailemariam et al. [82]	71.40 (70.13–72.67)	70.00 (68.73–71.27)	71.20 (69.93–72.47)
Kefeni et al. [83]	100.00 (97.09–102.91)	100.00 (97.09–102.91)	100.00 (97.09–102.91)
Awoke et al. [84]	100.00 (97.65–102.35)		100.00 (97.65–102.35)
Abdeta et al. [85]	27.80 (26.33–29.27)	70.30 (68.83–71.77)	56.40 (54.93–57.87)
Addis et al. [86]	62.50 (61.64–63.36)	91.70 (90.84–92.56)	80.00 (79.14–80.86)
Mitiku et al. [87]	62.50 (60.68–64.32)		62.50 (60.68–64.32)
Seid et al. [88]	66.70 (61.38–72.02)		66.70 (61.38–72.02)
Oumer et al. [89]	80.00 (77.86–82.15)		80.00 (77.86–82.15)
Guteta et al. [90]	75.80 (71.17–80.43)		75.80 (71.17–80.43)
Gebremedhin et al. [91]	80.00 (77.94–82.06)		80.00 (77.94–82.06)
Abate et al. [92]	90.90 (87.27–94.53)	100.00 (96.37–103.63)	93.80 (90.17–97.43)
Overall	**72.73 (67.018–78.44)**	**84.69 (78.78–90.59)**	**74.47 (69.92–79.01)**
I^2 (%)	**99.8%**	**99.7%**	**99.7%**
***P* value**	**< 0.001**	**< 0.001**	**< 0.001**

Table 6 Subgroup analysis of Pooled prevalence of MDR of *Pseudomonas* and *Acinetobacter* species in clinical Sample

Subgroups	Category	No of studies	No of isolates tested, N	Pooled prevalence of MDR (%)	95% CI	Heterogeneity test (I^2)	*P*-value	Heterogeneity between groups (*p*-value)
Type of samples	Ear discharge	18		75.41	(68.42, 82.4)	98.3%	< 0.001	< 0.001
	Clean catch mid-stream urine	11		80.19	(69.38, 90.99)	99.7%	< 0.001	
	pus aspirates, and wound swab	3		78.08	(53.34, 102.80)	99.4%	< 0.001	
	Clinical sample	19		77.63	(65.94, 89.32)	99.9%	< 0.001	
	Sputum	10		62.64	(46.00, 78.85)	99.9%	< 0.001	
	Ascitic fluid	1		50.0	(47.38,52.62)	0	-	
	Sputum and Blood	1		20.0	(15.52, 24.48)	0	-	
	Blood samples	2		48.73	(46.28, 51.18)	89.0%	< 0.001	
	Total pooled	65		72.73	(67.018–78.44)	99.8%	< 0.001	
Region	Addis Ababa	8		68.53	(57.1, 79.80)	99.8%	< 0.001	< 0.001
	Amhara	30		78.31	(71.39, 85.24)	99.6%	< 0.001	
	Oromia	9		63.64	(40.64, 86.6)	99.8%	< 0.001	
	Tigray	4		72.52	(33.78,111.27)	99.9%	< 0.001	
	Harari	3		85.86	(61.100, 10.64)	99.8%	0.003	
	Sidama	4		67.68	(37.86, 97.50)	99.8%	0.002	
	SNNPR	5		62.72	(50.27, 75.18)	99.4%	0.007	
	Different part of Ethiopia	2		60.64	(34.86,86.41)	99.8%	0.001	
	Total pooled	65		72.73	(67.018–78.44)	99.8%	< 0.001	
Publication year	< 2021	33		69.30	(61.83,76.63)	99.7%	< 0.001	0.204
	≥ 2021	32		76.57	(67.99,85.20)	99.9%	< 0.001	
	Total pooled	65		72.73	(67.018–78.44)	99.8%	< 0.001	
Study population type	All age groups	45		73.83	(66.83, 80.85)	99.8%	0.003	< 0.001
	Children < 15 years	7		69.03	(58.83, 79.23)	99.9%	< 0.001	
	Adult Patients	13		63.54	(31.64, 95.45)	99.9%	< 0.001	
	Total pooled	65		72.73	(67.018–78.44)	99.8%	< 0.001	
Sample size	< 300	38		72.35	(64.19, 80.52)	99.7%	< 0.001	0.800
	≥ 300	27		73.23	(64.26, 82.20)	99.9%	< 0.001	
	Total pooled	65		72.73	(67.018–78.44)	99.8%	< 0.001	

Table 7 Sensitivity analysis of the included studies

Author	Estimate	95% CI
Abera *et al* [30]	6.565	5.648–7.483
Dereje et al. [31]	6.871	5.990- 7.843
Misha et al. [32]	6.846	5.876–7.817
Endaylalu et al. [33]	6.571	5.629–7.511
Getaneh et al. [34]	6.733	5.773–7.693
Gorems et al. [35]	6.722	5.762–7.682
Hailu et al. [36]	6.513	5.587–7.439
Gashaw et al. [37]	6.819	5.851–7.787
Chernet et al. [38]	6.888	5.913–7.863
Molla et al. [39]	6.830	5.864–7.795
Muluye et al. [40]	6.671	5.716–7.625
Muleta et al. [41]	6.728	5.767–7.688
Hailegiyorgis et al. [42]	6.746	5.784–7.708
Tolera et al. [43]	6.887	5.910- 7.865
Seid et al. [44]	6.664	5.710- 7.618
Tadesse et al. [45]	6.804	5.838–7.770
Girma et al. [46]	6.780	5.832–7.762
Negash [47]	6.909	5.925- 7.893
Nurahmed et al. [48]	6.843	5.873–7.813
Hailu et al. [49]	6.775	5.810–7.740
Regassa et al. [50]	6.776	5.812–7.740
Atlaw et al. [51]	6.589	5.644–7.534
Sisay et al. [52]	6.830	5.859–7.801
Gebre et al. [53]	6.709	5.752–7.666
Temesgen et al. [54]	6.823	5.853–7.794
Tilahun et al. [55]	6.733	5.772–7.693
Dessie et al. [56]	6.792	5.825- 7.760
Haile et al. [57]	6.724	5.764–7.684
Moges et al. [58]	6.911	5.926–7.897
Assefa et al. [59]	6.882	5.907–7.858
Asmare et al. [60]	6.871	5.896–7.846
Alebel et al. [61]	6.746	5.784–7.708
Henok et al. [62]	6.806	5.838- 7.774
Alelign et al. [63]	6.856	5.882- 7.819
Tilahun et al. [9]	6.594	5.655–7.533
Tilahun et al. [64]	6.743	5.782–7.704
Regasa, et al. [65]	6.771	5.807- 7.734
Adugna, et al. [66]	6.901	5.921–7.882
Adhanom et al. [67]	6.880	5.907–7.853
Genetu *et al.* [68]	6.801	5.835–7.767
Worku et al. [69]	6.751	5.790–7.712
Legese et al. [70]	6.843	5.860–7.830
Birru et al. [71]	6.895	5.921–7.869
Tadesse et al [45]	6.762	5.799–7.726
Teweldmedhin et al. [72]	6.735	5.774–7.696
Motbainor et al. [73]	6.755	5.792–7.718
Assefa et al. [74]	6.790	5.827–7.752
Ejerssa, et al. [75]	6.891	5.918–7.864
Mulu et al. [76]	6.813	5.842–7.784
Belayhun et al. [77]	6.7820988	5.817–7.747
Wasihun et al. [78]	6.662	5.706–7.616
Sewunet et al. [79]	6.767	5.804–7.731
Tekele et al. [80]	6.765	5.801–7.729
Mekonnen et al. [81]	6.681	5.727–7.636
Hailemariam et al. [82]	6.828	5.850–7.806
Kefeni et al. [83]	6.837	5.869–7.805
Awoke et al. [84]	6.863	5.894–7.832
Abdeta et al. [85]	6.746	5.789- 7.704
Addis et al. [86]	6.894	5.901–7.886
Mitiku et al. [87]	6.839	5.867–7.812
Seid et al. [88]	6.805	5.841–7.768
Oumer et al. [89]	6.841	5.871- 7.812
Guteta et al. [90]	6.648	5.696–7.599
Gebremedhin et al. [91]	6.844	5.873 7.815
Abate et al. [92]	6.7663131	5.8026–7.730
Combined	**6.780**	**5.823–7.737**

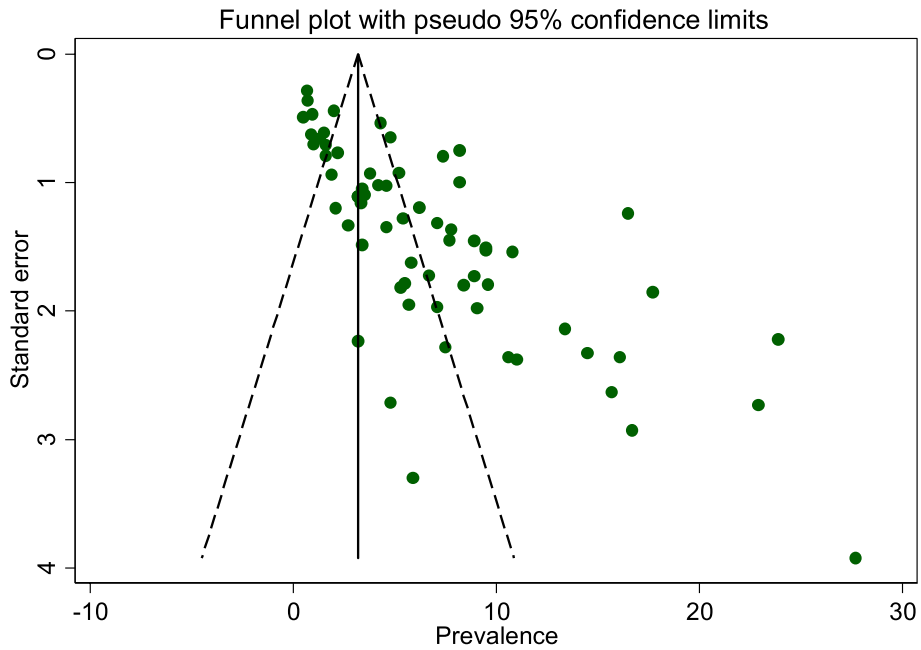

Fig. 13 Funnel plot on the prevalence of *Pseudomonas and Acinetobacter species* among pediatrics in Ethiopia illustrates publication bias

Table 8 Egger's test statistics of the prevalence of *Pseudomonas and Acinetobacter species* among pediatrics in Ethiopia illustrating the absence of publication bias

Std-Eff	Coef	Std. Err	T	P >|t|	95% CI
Slope	-.893124	0.5295927	- 1.69	0.097	−1.9514, 0.165183
Bias	5.503787	.5729064	9.61	< 0.001	4.35893, 6.64865

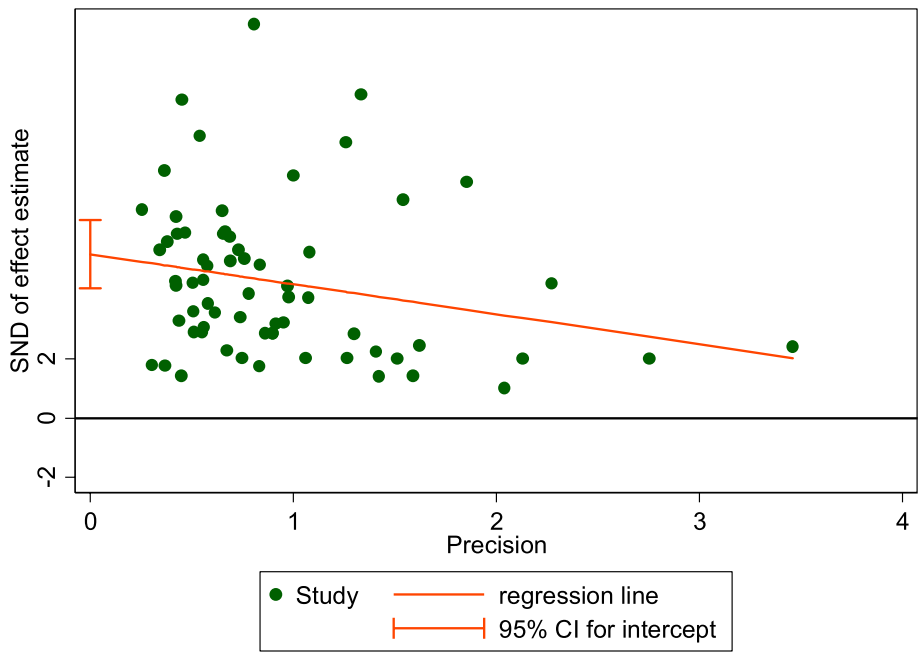

Fig. 14 Egger's test graph depicting the presence of publication bias

Table 9 Trim and fill analysis of the prevalence of *Pseudomonas and Acinetobacter species* among pediatrics in Ethiopia

Method	Pooled est	95% CI		Asymptotic		No. of studies
		Lower	Upper	z-value	*p*-value	
Fixed	3.556	3.131	3.581	29.271	< 0.001	65
Random	6.780	5.823	7.737	13.887	< 0.001	
Test for heterogeneity: Q = 1002.016 on 64 degrees of freedom ($p < 0.001$)						
Moment-based estimate between studies variance = 13.049						
Trimming estimator: Linear						
Meta-analysis type: Fixed-effects model						
Iteration	Estimate	Tn	# To trim		Diff	
1	3.356	1831	24		2145	
2	2.328	2010	29		358	
3	2.104	2033	30		46	
4	2.059	2042	30		18	
5	2.059	2042	30		0	
Filled						
Meta-analysis						
Method	Pooled est	95% CI		Asymptotic		No. of studies
		Lower	Upper	z-value	*p*-value	
Fixed	2.059	1.851	2.267	19.369	< 0.001	95
Random	2.544	1.506	3.581	4.804	< 0.001	

Test for heterogeneity: Q = 2100.498 on 94 degrees of freedom ($p < 0.001$)

Moment-based estimate between studies variance = 23.668

Table 10 Meta-regression of prevalence and MDR by multiple categories of studies included in the systematic review and meta-analysis

	Type of variables	Exp(b)	SE	T	P	95% CI
Prevalence	Total isolates	1.215958	.0412401	5.77	**< 0.001**	1.132633—1.305412
	Sample size	1.018553	.0090198	2.08	0.052	.9998482- 1.037608
MDR	Total isolates	.9542044	.1845152	−0.24	0.813	.6261308—1.454179
	Sample size	.9514895	.0245331	−1.93	0.078	.8995102- 1.006473

clinical samples across Ethiopia, with pooled estimates exceeding 70% and Resistance rates for key antibiotics were high: amoxicillin-clavulanic acid (83.7–87.2%), tetracycline (89.1–87.2%), gentamicin (47.7–58.9%), ceftriaxone (57.3–79.7%), and meropenem (37.6–44.4%). Ethiopia shows some of the highest resistance rates globally, with limited treatment options due to widespread resistance to beta-lactams, carbapenems, and aminoglycosides. These findings underscore an urgent need for effective infection control, strengthened AMR surveillance, and revised treatment protocols. Immediate action is essential to improve stewardship, enforce responsible antibiotic use, and contain the spread of resistant pathogens.

Abbreviations

AMR	Antimicrobial resistance
CI	Confidence interval
CLSI	Clinical Laboratory Standards Institute
MDR	Multidrug resistance
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
STATA	Statistics and data
WHO	World Health Organization

Supplementary Information

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Supplementary Material 1. Supplementary Table 1: Critical appraisal checklist of quantitative studies of Acinetobacter and pseudomonas species infections in Ethiopia

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Clinical trail
Not applicable.

Author' contributions
MT and AG conceived and designed the study. AS, and AGS participated in article search and data extraction. MT, HD, and AS conducted a quality assessment of the included studies and performed the statistical analysis and interpretation of the data. MT drafts the manuscript. MT, AG, and AS check the validity and monitor the overall process. MT, AGS, and AS critically reviewed the manuscript. All the authors read and approved the final manuscript.

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Consent for publication
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Author details
[1]Department of Medical Laboratory Science, College of Medicine and Health Sciences, Wollo University, P.O. Box 1145, Dessie, Ethiopia.

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