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REVIEW ARTICLE

Magnitude of Health Care Associated Infections and its Clinical Predictors in Ethiopia: A Systematic Review and Meta-Analysis

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Abstract

Background Health care-acquired infections (HCAIs) are the growing global public health problems facing today requiring an immediate collaborative action of stockholders to be prevented and controlled. Thus, this study was aimed to assess the magnitude and clinical related factors of HCAIs in Ethiopia.

Methods Articles were extensively searched in bibliographic databases and grey literatures using entry terms or phrases. Studies meeting eligibility criteria was extracted in Ms excel and exported in to STATA version 17 software for statistical analysis. A random-effect model was used to compute the pooled magnitude of HCAIs using meta-prop. The heterogeneity was quantified by using the I^2 value. Publication bias was assessed using a funnel plot and Egger's test. Sensitivity analysis, meta-regression and subgroup analysis were computed.

Result Of the 1707 studies identified, 33 studies were selected for meta-analysis of magnitude of HCAIs. The overall pooled prevalence of HCAIs in Ethiopia was 37% (95% CI: 27.0–47.0%). The predominant bacterial aetiologies were *E. coli.* There was no single study effect and publication bias. Diabetes mellitus, comorbidities, contaminated wound, history of UTI and history of admission in ICU were statistically significant clinical predictors of HCAIs.

Conclusion the pooled prevalence of HCAIs have alarmingly increased which underscores the importance of implementation of personalized infection prevention and control approach which identifies patients at risk of HCAIs from the point of admission maximizes the potential for prevention of HCAIs.

Keywords HCAIs · Bacterial infections · Clinical predictors · Ethiopia · Systematic review and meta analysis

Abbreviations

AMR	Antimicrobial Resistance
HCAIs	Health Care Associated Infections
ICU	Intensive Care Unit
IPC	Infection Prevention and Control
MDR	Multiple Drug-Resistant
PRISMA	Preferred Reporting Items for Systematic Review and Meta-analysis
WHO	World Health Organization

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1 Introduction

Healthcare-associated infections (HCAIs) are infections that are contracted while receiving medical care in a hospital or other healthcare facility [1]. HCAIs include pneumonia (clinically defined pneumonia or ventilator-associated pneumonia), catheter associated urinary tract infection (CAUTI), surgical site infection (SSI), bloodstream infection (BSI), which can be either laboratory-confirmed bloodstream infection or central-line associated bloodstream infection. Other HCAIs occur in the bones, joints, central nervous system, cardiovascular system (e.g. endocarditis) and in the skin and soft tissue [2]. HCAIs are not only as an issue of patient safety but also as a major driver of antimicrobial resistance (AMR) [3]. Antibiotic resistance has led to the development of "superbugs" that no longer respond to the current treatment modalities. The array of antibiotics available to treat these infections is dwindling with very few antibiotics in the pipeline [4, 5]. Most pathogenic microorganisms have the capability of developing resistance to antibiotics, most antibiotic-resistant bacteria originally emerged in hospitals [6].

HCAIs and AMR are growing global public health problems [7–9]. According to the World Health Organization (WHO) 2022 report HCAIs continue to pose a concern to public health on a global scale, affecting hundreds of millions of people each year, with the majority of infections occurring in low- and middle-income countries (LMICs) [10]. Recent reports in 2022 identified AMR as one of the top 3 serious cross-border threats by causing an with estimates of 1.27 million deaths worldwide annually [11] and about 75% of the health burden of AMR is due to HCAIs [12]. Similarly, bacterial AMR has been responsible for an estimated 4·95 million deaths [13]. If nothing is done, it is estimated that AMR will cause more than 10 million deaths by the year 2050 [14].

According to a global antimicrobial resistance data of 2019, from an estimated 13·7 million infection-related deaths in 2019, there were 7·7 million deaths associated with the 33 bacterial pathogens (both resistant and susceptible to antimicrobials) [15]. *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Streptococcus pneumoniae*, *Acinetobacter baumannii*, and *Pseudomonas aeruginosa* are the leading pathogens for deaths associated with resistance [13, 15]. In addition to increasing morbidity and death, HCAIs and AMR also place a heavy financial strain on the healthcare system [9, 16]. AMR is more challenging to treat infections effectively and raises the possibility that patients was experience catastrophic effects, endure a lengthy illness and induces complications of their diseases [14]. The emergence of AMR is influenced by individual, behavioral, environmental or policy level, community and institutional factors [6, 17–19]. Particularly, inappropriate use of antibiotics, patients not finishing the entire antibiotic course, over-prescription of antibiotics, poor infection control in health care settings, poor hygiene and sanitation practices in treatment of patients, the continued use of antibiotics in agriculture are the most common predictors for the development of AMR [6, 17, 18].

The WHO calls for the need to contain the spread of AMR from all possible sources to minimize the problem of AMR globally [20]. A multifaceted approach such as One Health approach have been initiated in 2017 [12] followed by the national action plan initiative on AMR by European Union (EU) and the European Economic Area (EEA)countries in 2018. These initiatives have played an active role in the fight against AMR by delivering innovative, effective and sustainable responses to AMR, and reinforces the research agenda on AMR [12]. Implementation of effective Infection Prevention and Control (IPC) measures in health care settings is another alternative approach for preventing HCAIs and AMR [21, 22].

The burden of HCAIs is disproportionately high in LMICs countries like sub-Saharan Africa (SSA) including Ethiopia [10]. Despite of this, there is lack of coordinated epidemiological surveillance system; infection prevention and control practices (IPC) training has been given but the burden of HCAIs is still continued to be highly increased; comprehensive evidence showing the exact burden of bacterial aetiologies and most common predicting factors affecting HCAIs are lacking. Moreover, the finding of HCAIs, their aetiologies were inconsistently reported in previous studies of Ethiopia in assessing the true scale of the problem. Certain evidences in Ethiopia had reported the prevalence of HCAIs from 6.9% [23] to 89.32% [24]. Thus, there is a need to have an up-dated pooled evidence using systematic review and meta-analyses which can offer more accurate than those produced from the individual primary studies included in a review. Therefore, the aim of the present study is, to evaluate the pooled prevalence of HCAIs, their aetiologies and clinical related factors of HCAIs in Ethiopia for the last 10 years from 2013 to 2023.

2 Methods and Materials

2.1 Design and Protocol Registration

This systematic review and meta-analysis are designed to estimate the pooled magnitude of health care associated bacterial infections and associated factors in Ethiopia. The article was registered in a Prospective Register of Systematic Reviews (PROSPERO) registration number of CRD42023410164 available at https://www.crd.york.ac.uk

/prospero/export_details_pdf.php. The result was reported based on Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P) 2020 statement of updated guidelines [25] (Supplementary File-1).

2.2 Research Questions

What is the pooled prevalence of HCAIs in Ethiopia? What are the clinical predictors affecting HCAIs? What are the bacterial aetiologies of HCAIs in Ethiopia?

2.3 Eligibility Criteria

A selection criteria checklist for study eligibility is developed by the author prior to identifying appropriately published relevant full-text articles either in local or international journals. A selection criteria checklist for study eligibility was developed by the author prior to searching literatures as indicated in the following concepts.

- **Inclusion Criteria**: All studies which met at least the following criteria were included in the review process. These were.
    - **Participants**: all patients with a history of hospital admission.
    - **Publication status**: Either published in peer-reviewed journals or unpublished studies.
    - **Study Area**: Studies conducted in Ethiopia.
    - **Time frame**: All studies done from January 1, 2013 to July 25, 2023.
    - **Study design**: Observational studies (Cross-sectional and cohort).
    - **Study setting**: All studies conducted at the health institution level (inpatients).
    - **Language**: This review includes studies published in English language.
    - **Outcome**: Healthcare associated infections reporting bacterial isolates.

Exclusion studies were excluded if studies which did not report the outcome of interest, reviews about HCAIs and studies without information on total studied isolates.

2.4 Data Source and Search Strategy

This review was conducted in line with PRISMA guideline. A comprehensive search of databases was performed to identify all relevant articles published on healthcare-associated infection in Ethiopia from PubMed /MEDLINE, Epistemonikos, HINARI, African Index Medicus, WHO Afro Library Database and other graye literature (Google scholar and Google) using keywords and Boolean operators "OR" and "AND "combination (Supplementary File-2).

We limited the search to the last 10 years to have contemporaneous data. The search terms were combined using the Boolean operators "OR" and "AND" to fit the advanced searching of articles. In addition to accounting for the studies' omission during electronic database searches, a direct google search was carried out using listed references in included articles. The comprehensive and extensive searching strategy was employed using condition, context, population, and outcome of interest (CoCoPop) formulating questions and searching.

2.5 Study Selection

Articles were identified from databases and other sources. Duplicates was removed using endnote reference manager and Rayyan online duplicate checks to screen the title and abstract of all potentially eligible studies. The full texts of the articles were used to determine whether the study met the selection criteria or whether the eligibility of the articles was in doubt. The full text of potentially eligible studies that reported the prevalence or epidemiology of HCAIs; their antimicrobial resistance profile and associated risk factors were added by AG, FB, AA, AM and FY to the collections for extraction. Disagreement during selection was fixed through discussion and getting to consensus among reviewers.

2.6 Quality Assessment

The quality of the articles was assessed by AG, FB, AA, AM, AM and SW. The Joanna Brigg Institute (JBI) quality assessment manual was used to assess the methodological validity of each study design. The JBI checklist for quantitative studies assesses study quality based on eight criteria, including bias, confounding, the validity of measurement of exposures and the outcome and the validity of methods of analyses. Using the critical appraisal checklists, studies were reviewed and articles with an average score of 50–75% were considered as good quality while greater than 75% score was defined as high quality. Finally, articles with good and high quality were included in this systematic review and meta-analysis (Supplementary File-3).

2.7 Outcome Measurement

The primary outcome variable of this systematic review and meta-analysis was the magnitude of health care associated bacterial infections in Ethiopia. The second outcome was the possible clinical related factors associated with HCAIs.

Additional outcomes of this study were to assess the bacterial aetiologies of HCAIs.

2.8 Data Extraction

Data from the eligible studies was extracted by AG, AA, FY and FB in Microsoft Excel sheets (Supplementary File-4). The information extracted from each study includes the name of the first author, publication year, setting, region, types of infections (HCAIs), age group of participants, study design used, type of sample, sample size, type of bacterial isolate, number of isolates, common risk factors with their effect size and confidence interval as well as quality scores of each study.

2.9 Data Synthesis and Statistical Analysis

The data extraction was done using a Microsoft Excel worksheet. The point estimate and 95% confidence interval of the prevalence of HCAIs; their multi-drug resistance and associated risk factors for the studies fulfilling inclusion criteria was calculated. The meta-analysis was done by using STATA version 17 (StataCorp LLC, United States) with metan commands. The proportion of HCAIs was computed using metaprop which is an extension of metan. DerSimonian Laird method was used to estimate the between-study variance. Cochrane's Q test and I^2 statistics were used to assess the heterogeneity [26]. A p-value of >0.05 was used to declare the effect is homogeneous. Therefore, a random effect model was used to adjust the observed variability.

The presence of heterogeneity was further analysed for its source using subgroup analysis based on year, setting, region, types of infection (HCAIs), age group of participants, study design used, type of sample, sample size, type of bacterial isolate, common risk factor variables. Likewise, meta-regression was also conducted to identify the possible source of heterogeneity. Lastly, a sensitivity analysis was performed to examine the influence of a single study on the overall estimate. Furthermore, publication bias was assessed by visual observation of the symmetry of the funnel plot and Egger's test statistics [27, 28].

3 Result

3.1 Selection and Identification of Studies

A total of 1707 articles were retrieved from databases. After 698 articles were removed through duplicate check only 1009 articles were remained. From the remaining, 964 articles were excluded after reviewing the titles and abstracts of the study. Finally, 46 full-length articles were thoroughly reviewed by predetermined eligibility criteria, and 33 studies were found to be eligible for inclusion in qualitative and quantitative analysis or meta-analysis. The preferred reporting items for systematic review and meta-analysis (PRISMA checklist 2020) were followed (Fig. 1).

3.2 Study Characteristics

In this systematic review and meta-analysis, a total of 33 published articles were included. The studies involved 9297 study participants. The sample size of the studies ranged from 107 to 716. The studies were conducted in one city administration (i.e., Addis Ababa) and five national regional states of Ethiopia (i.e., Amhara, Harari, Oromia, Tigray, SNNPR). Among included studies 31 studies employed a cross-sectional study design. Of the studies included in this systematic review and meta-analysis, 17 studies were conducted in all age groups. Studies from 2014 to 2023 were include in this study. Most of studies, five of each were reported from Addis Ababa and Dessie areas. From a total of 3153 reported isolates, 1744 isolates were multi-drug resistant bacterial pathogens reported in 21 studies (Table 1).

4 Magnitude and Bacterial Aetiologies of HCAIs

In this systematic review and meta-analysis, the random effects model showed that the overall pooled prevalence of HCAIs in Ethiopia was 37% (95% CI: 27.0–47.0%). Moreover, the prevalence of HCAIs was reported from 7 to 91% (Fig. 2). The pooled prevalence of HCAIs was computed from 33 articles published from 2014 to 2023. The lowest prevalence was reported during 2018 and the highest prevalence was reported in 2023. Of all studies included in this meta-analysis, eight studies have reported more than 50% prevalence of HCAIs of which three articles had reported above 80% of HCAIs in Ethiopia. In this study, there was substantial heterogeneity with an I^2 of 99.36% (Fig. 2).

A cumulative meta-analysis result showed that the number of studies after 2017 were increased compared to before 2017 but there were no differences in effect size. Moreover, the trend analysis showed that the prevalence of HCAIs was varied across time and the maximum prevalence was recorded during 2022 (Fig. 3).

A total of 3542 clinical isolates were identified among hospitalized patients involved in the primary studies. Among, these isolates 2401 (67.79%) and 1141 (32.21%) isolates respectively were gram negative and gram-positive bacteria. We found 11 Gram-negative bacterial isolates among patients with health care-associated infection in Ethiopia. The predominant bacterial isolate was found to be 26.23%

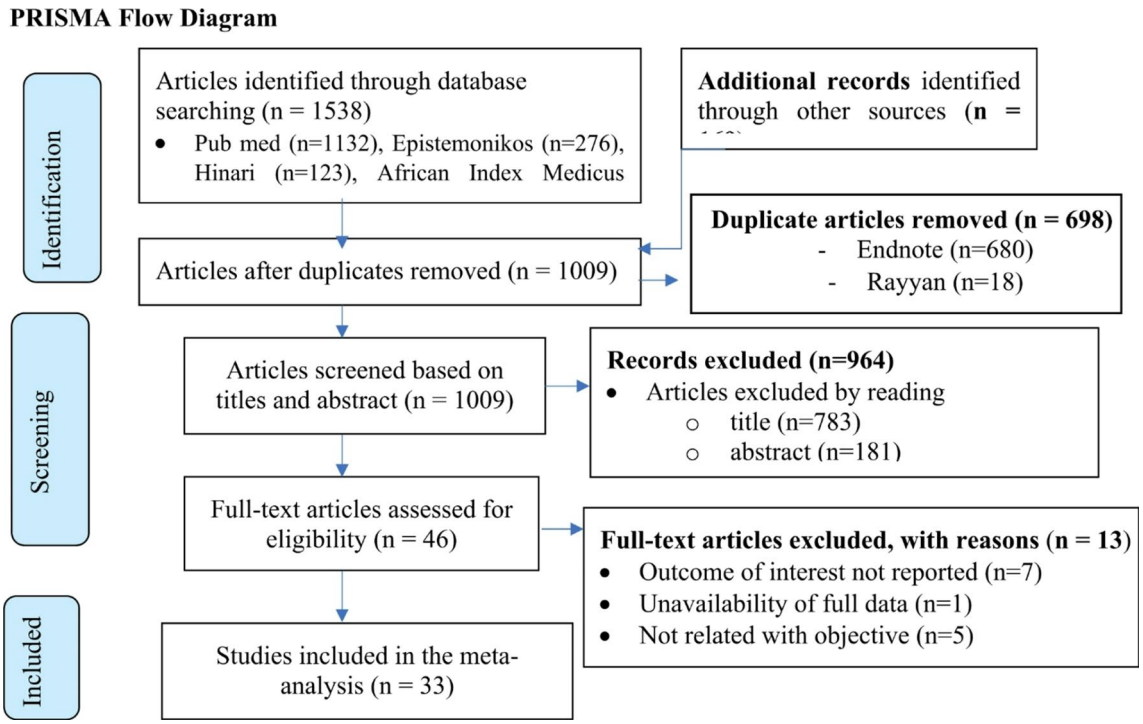

Fig. 1 Flow diagram for the selection of eligible studies

(929/3542) *E. coli* followed by 19.48% (690/3542) *Klebsiella* species and 16.85% (597/3542) *S.aureus* (Table 2).

4.1 Heterogeneity Exploration for HCAI

The existence of heterogeneity was assessed within the included studies. Heterogeneity was assessed using different techniques such as visual (subjective) techniques using Galbraith plot to check whether all the points lie within the 95% confidence bounds and Forest plot to check whether the confidence intervals of studies (the summary effects) overlap with each other. To avoid the subjective nature of visual techniques I^2 test was used. Consequently, there was substantial heterogeneity across twenty-nine included studies ($I^2 = 99.36\%$).

Therefore, we have used certain strategies to address heterogeneity such as carrying-out the meta-analysis using Random effect model followed by exploring heterogeneity using subgroup analysis and meta regression. Moreover, to exclude studies sensitivity analysis was performed.

The Galbraith plot showed that none of studies were outside of the 95% confidence interval. Similarly, in the leave one-out meta-analysis (Sensitivity) analysis none of the omitted analysis lies outside the confidence interval for combined analysis. Subgroup analysis was also done but source of heterogeneity was not identified (Supplementary File-5).

4.2 Subgroup Analysis

The proportion of HCAIs between studies with good and high quality was equal. About two-third of studies were conducted among patients with suspected HCAIs with a pooled prevalence of 41% (95% CI: 21%, 55%). More than 80% of studies (28 out of 33 studies) were reported during after 2018. The prevalence of HCAIs based on year category was 57% (95% CI: 37%, 77%) from 1014 to 2017 vs. 34% (95% CI: 23%, 45%) from 2018 to 2023 ($P<0.001$) (Fig. 4). Out of 33 studies, 14 studies were reported from the Amhara region with a pooled prevalence of 38% (95% CI: 21%, 56%). Similarly, an equal number of studies were reported from Addis Ababa, SNNRP and Oromia. Considering study areas, an equal number of five studies were reported from Addis Ababa and Dessie from Amhara region. The highest pooled prevalence of HCAIs was reported in the Addis Ababa (51%), Oromia (41%), and Amhara region (38%) (Fig. 5). The majority of studies (27 studies) were used a minimum sample size of less than 384 with a pooled prevalence of 38% (95% CI: 21%, 49%) (Fig. 6). Moreover, nearly all studies ($n=31$) were a cross-sectional study with a pooled prevalence of 39% vs. a 14% in cohort studies. Seventeen studies were conducted among participants of all ages and reported 37% of HCAIs. Similarly, the same prevalence was reported from five studies conducted in neonates (37%) (Fig. 7).

Table 1 Characteristics of the included studies

	Author	Publication year	Region	study area	Design	Quality	age	SS	M	F	culture positive	MDR
1	Kahsay et al. [29]	2014	Amhara	Debre Markos	CS	Good	>18	184	61	123	73	0
2	Dereje et al. [30]	2017	AA	Addis Ababa	CS	Good	>10	210	0	210	122	0
3	Motbionor et al. [31]	2020	Amhara	Bahir Dar	CS	Good	All	238	129	109	20	20
4	Gashaw et al. [32]	2018	Oromia	Jimma	CS	Good	Neonate	197	**0**	**0**	118	38
5	Sorsa et al. [33]	2019	Oromia	Assela	CS	Good	Neonate	303	**0**	**0**	88	0
6	Gemechu et al. [34]	2021	Oromia	Meda walabu	CS	Good	All	207	125	82	51	0
7	Tolera et al. [23]	2018	Harari	Harar	CS	Good	All	400	171	223	28	23
8	Alebel M. [35]	2021	Amhara	Bahir Dar	CS	High	All	270	147	123	95	77
9	Yitayh et al. [36]	2021	Amhara	Bahir Dar	CS	Good	All	716	403	313	134	89
10	Oumer et al. [37]	2021	SNNPR	Arba Minch	CS	High	>18	231	156	75	39	37
11	Tefera et al. [38]	2021	Amhara	Debre Markos	CS	High	All	242	172	70	71	0
12	Zakir et al. [39]	2021	SNNPR	Arba Minch	CS	High	Neonate	212	129	83	72	63
13	Tilahun et al. [40]	2022	Amhara	Dessie	CS	High	All	423	226	197	75	66
14	Abayneh et al. [41]	2022	SNNPR	Mizan-Tepi	Cohort	Good	All	262	106	156	33	0
15	Alelign et al. [42]	2022	SNNPR	Arba Minch	CS	High	All	245	165	80	72	51
16	Sahle et al. [43]	2022	Amhara	Debre Berhan	CS	High	All	384	154	230	164	151
17	Tilahun M [24]	2022	Amhara	Dessie	CS	High	>5	384	180	204	343	251
18	Dessie et al. [44]	2016	AA	Addis Ababa	CS	High	All	107	51	56	90	75
19	Tamrie et al. [45]	2021	AA	Addis Ababa	CS	High	All	160	89	71	57	0
20	Fenta et al. [46]	2022	Amhara	Dessie	CS	High	Neonate	246	162	84	67	46
21	Shibabaw et al. [47]	2023	Amhara	Debre Berhan	CS	High	All	384	0	0	164	0
22	Gebremeskel et al. [48]	2022	SNNPR	Hawassa	CS	High	>18	280	148	132	38	27
23	Negussie et al. [49]	2015	AA	Addis Ababa	CS	Good	<12	201	110	91	56	0
24	Woldu et al. [50]	2020	Tigray	Mekelle	CS	High	Neonates	317	190	127	117	0
25	Mekonene et al. [51]	2021	Amhara	Dessie	CS	High	All	254	145	109	34	28
26	Bizuayehu et al. [52]	2021	AA	Addis Ababa	CS	Good	>15	220	76	144	113	52
27	Mekonene et al. [53]	2023	Harari	Harar	CS	High	<5	332	139	213	80	53
28	Shenkute et al. [54]	2022	Amhara	Debre Berhan	CS	High	All	383	190	193	347	305
29	Ali et al. [55]	2023	Amhara	Dessie	CS	High	>15	338	87	251	41	38
30	Misha et al. [56]	2021	Oromia	Jimma	Cohort	Good	>18	251	125	126	38	0
31	Abamecha et al. [57]	2015	Oromia	Jimma	CS	Good	>15	150	76	74	114	102
32	Feleke et al. [58]	2018	Amhara	Gondar	CS	Good	All	260	108	152	173	152
33	Shakir et al. [59]	2021	Harari	Harar	CS	Good	All	306	125	181	26	0
							Total	9297	4145	4282	3153	1744

Keys: AA: Addis Ababa; CS: Cross sectional study; F: Female; M: Male; MDR: Multidrug resistant; SNNPR: Southern Nations and Nationalities and Peoples Region; SS: Sample Size

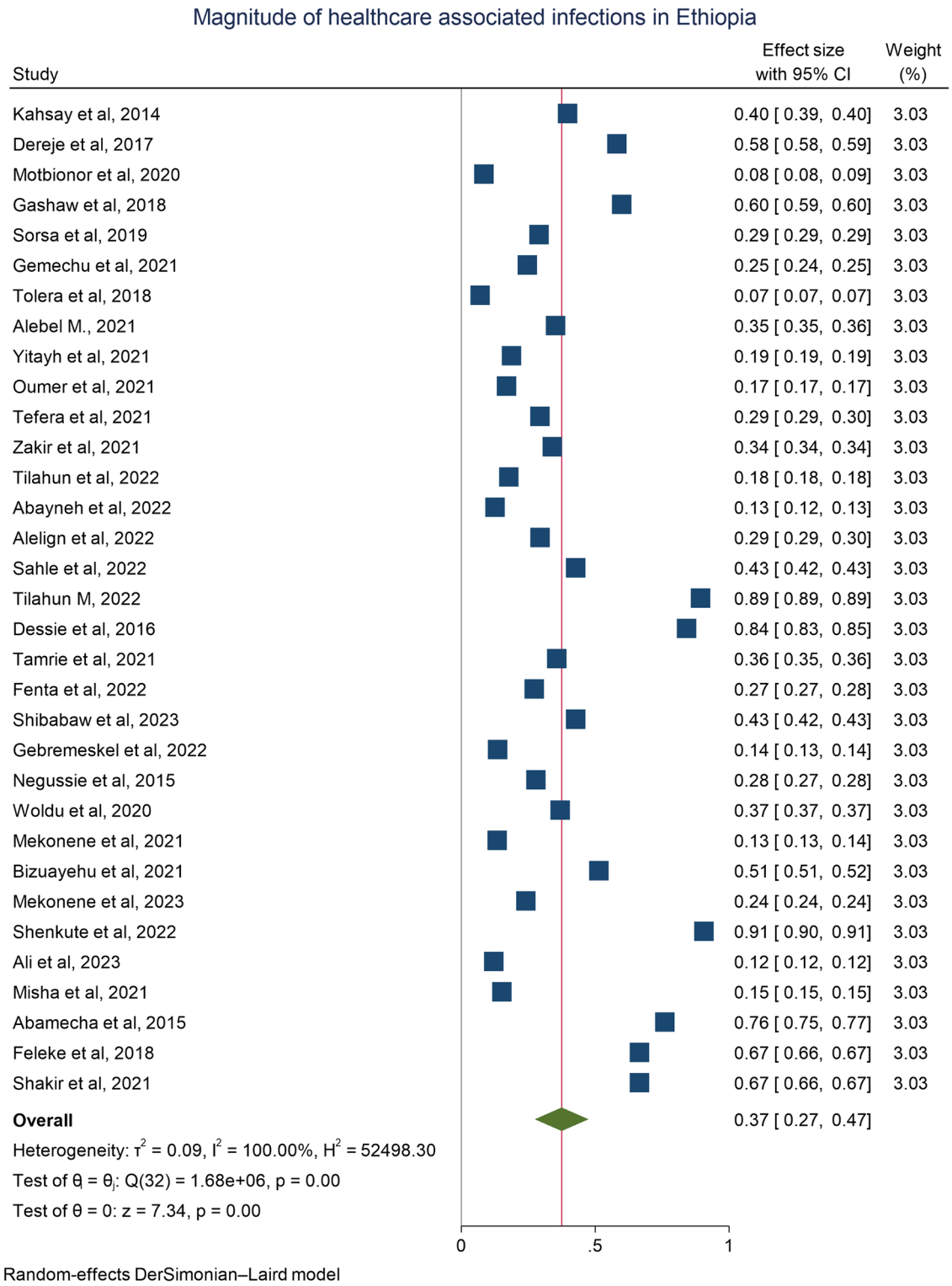

Fig. 2 Forest plot showing magnitude of health care associated infections in Ethiopia

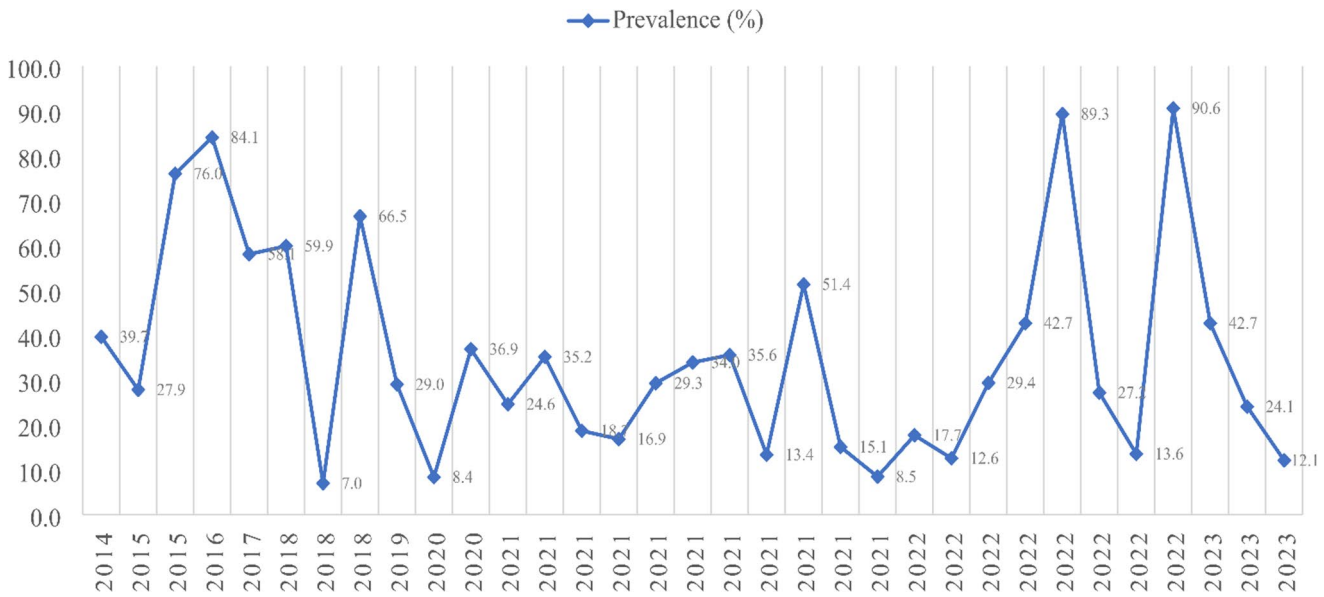

Fig. 3 Trends of magnitude of health care associated infections in Ethiopia from 2014 to 2023

Table 2 Results of each bacterial type isolated from patients with HCAI

Gram reaction	Type of bacterial isolates	No. of studies	Total no. of culture-positive	Pooled prevalence rate
Gram positive ($n=1141$)	CoNS	19	173	4.88
	Enterococcus	11	160	4.52
	MRSA	4	151	4.26
	S.aureus	22	597	16.85
	Streptococcus spp	8	39	1.10
	VISA	1	11	0.31
	VRSA	1	10	0.28
Gram negative ($n=2401$)	*Acinetobacter* spp	13	122	3.44
	Citrobacter spp	22	143	4.04
	E. coli	25	929	26.23
	Enterobacter spp	17	95	2.68
	Klebsiella spp	24	690	19.48
	M.morgani	7	26	0.73
	N.gonorrhoeae	1	1	0.03
	P.aeruginosa	18	204	5.76
	Proteus spp	15	113	3.19
	Providencia spp	7	20	0.56
	Salmonella spp	4	9	0.25
	Serratia spp	8	30	0.85
	Others*	1	19	0.54
	Total isolates		**3542**	**100**

Others*: *Shigella* spp, *Proteus* spp, *Pseudomonas*, and S.Typhi

4.3 Meta-Regression Test

To investigate the impacts of active potential factors in the heterogeneity of prevalence of HCAI in Ethiopia, a random-effects meta-regression test has been done using DerSimonian–Laird method. Furthermore, meta-regression analysis was computed with each potential covariates individually with the effect size. In this analysis, 8 factors were explaining the variability between studies from 0.68% (Category of publication year) to 15.15% (organism type) by which this difference is not statistically significant for all these 8 covariates ($P>0.05$). The combined proportion of between study variance explained by multiple meta-regression was 55.58% (Table 3).

4.4 Publication Bias

Publication bias was assessed using funnel plot analysis where the symmetry of the funnel plot indicated the absence of publication bias for an overall pooled prevalence of HCAIs (Fig. 8). Even though it is subjective the symmetric distribution of the studies is indicative of the absence of publication bias. Egger's test statistics confirmed the absence of publication bias with p-value of 0.2571.

4.5 Clinical Predictors of HCAIs in Ethiopia

The effect size of clinical predictors was computed from the number of studies reporting the factors are two and above. Four studies were reported the significant association of diabetes mellitus, catheterization and advancement of hospital stay with HCAIs. Moreover, the pooled effect of diabetes

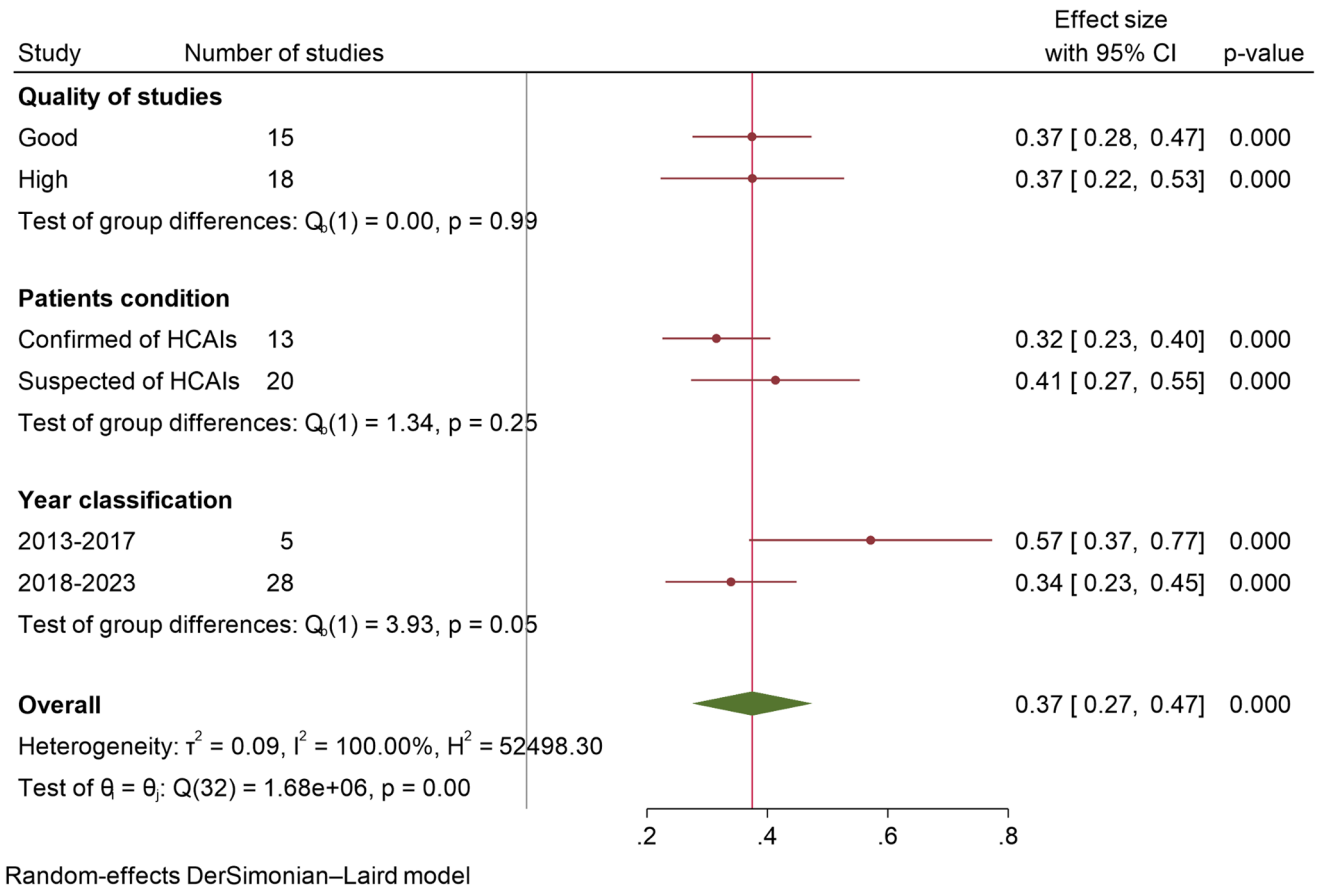

Fig. 4 Forest plot showing subgroup analysis of HCAIs by quality of studies, patients condition and year category

mellitus, comorbidities and/ or underlying diseases, contaminated wound, history of UTI and history of admission in ICU showed a statistical association with the development of HCAIs. The overall analysis showed a significantly increased risk of HCAIs among patients with diabetes mellitus (DM) (pooled OR = 5.97; 95% CI 2.26–15.76; $p < 0.001$), comorbidities and/ or underlying diseases was (OR: 3.91; 95% CI; 2.22–6.90; $p < 0.001$), contaminated wound (OR 7.44, 95% CI; 2.17–25.44; $p < 0.001$), history of UTI (OR:2.39; 95% CI; 1.38–4.14, $P < 0.001$) and history of admission in ICU (OR: 2.93; 95% CI: 1.32–6.51; $p = 0.001$) (Table 4).

5 Discussion

Health care-associated infections continues a global burden of infectious diseases. Particularly, it is common infectious diseases in resource-limited countries including Ethiopia. The increased prevalence rate of HCAIs alarms the need of immediate intervention strategies. This study evaluated the prevalence, multi-drug resistance status and clinical predictors HCAIs, and pathogens implicated in those infections among hospitalized patients in Ethiopia. The total number of studies included in this systematic review were 33, of which 31 were cross-sectional and whereas the remaining one study was cohort. The study found that 14 (42.4%) of studies reported the rate of HCAIs among hospitalized patients were reported in Amhara region. A total of 9297 individuals have been included in this study.

The national pooled prevalence of HCAIs in Ethiopia was found to be found 36% (95% CI: 26–48%). This finding indicates that HCAIs are highly prevalent in hospitalized patients and reflects inadequate implementation of infection prevention in Ethiopia. Hence, a multifactorial approach is required to manage HCAIs, with emphasis being placed on adequate antibiotic prophylaxis, aseptic wound care, and treatment adherence.

The finding of this meta-analysis was higher than the 12.76% of pooled prevalence of HCAIs reported in Africa [60], 15.5% in developing countries [61], 6.5% in Europe [62], and 16.94% and 16.96%in Ethiopia [63, 64], 9.0% in Asia [65], and 4% in United States [66]. The possible reasons for high prevalence rate of HCAIs in this study might be due to low hand hygiene practice, low level of job satisfaction, morally distressed nurses, resource constraints,

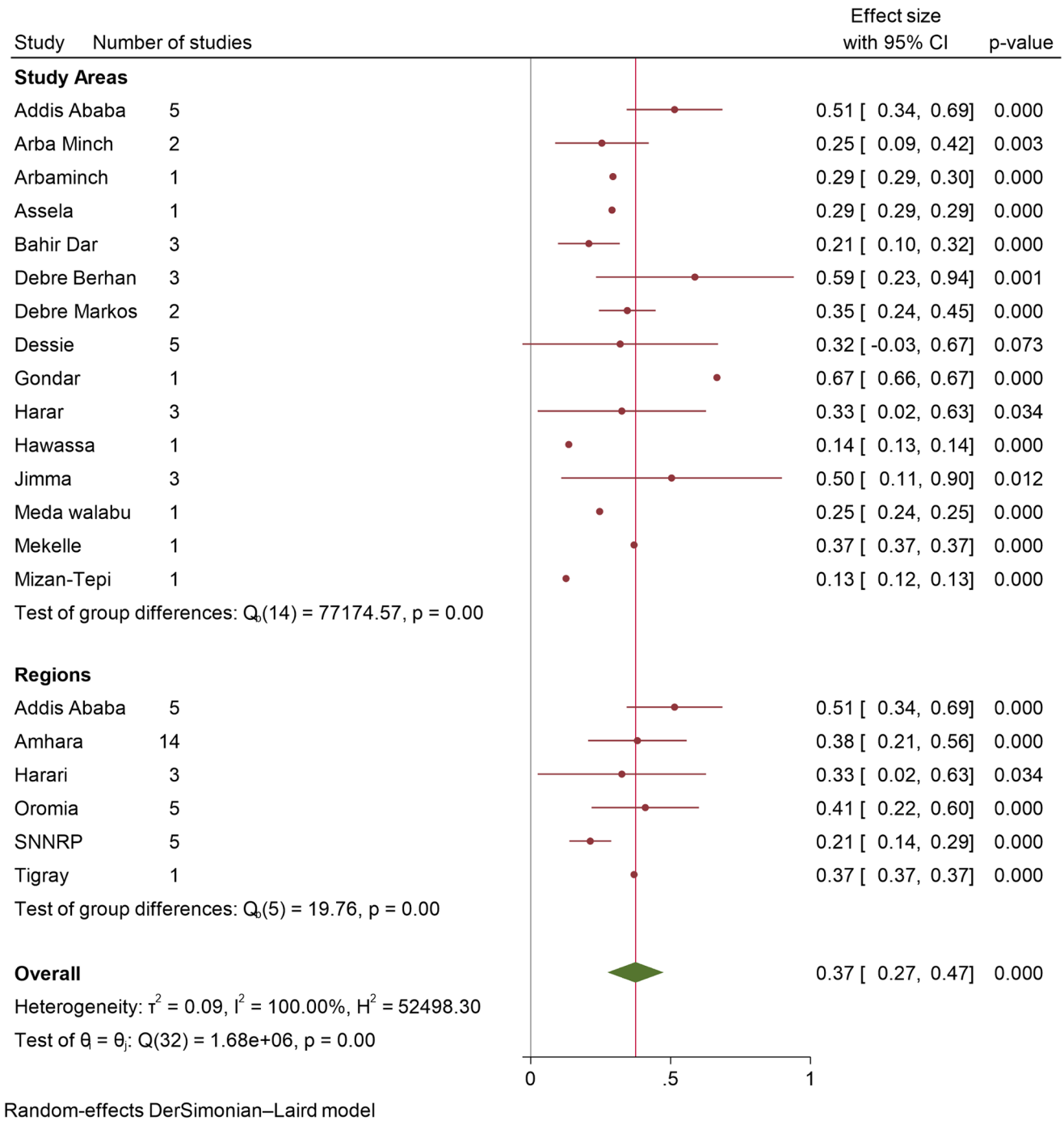

Fig. 5 Forest plot showing subgroup analysis of HCAIs by region and study area

low implementation of the nursing process, and less attention given to healthcare-associated infection, poor infection control and prevention practices due to limited infection prevention and control capacity [67]. This could be further supported by previous evidences that have shown poor rate of adherence to hand hygiene among healthcare workers in sub-Saharan Africa due to lack of knowledge and training, heavy workload and lack of infrastructure [68]. In addition, the number and/or representativeness of studies as well as methodological qualities of studies included in meta-analysis might, these differences could be attributable to irregular and varied use of antibiotics, low quality of personal hygiene, and inadequate environmental cleaning and infection control policies and compliances.

The present review revealed that the predominant pathogens associated with the development of HCAIs were gram

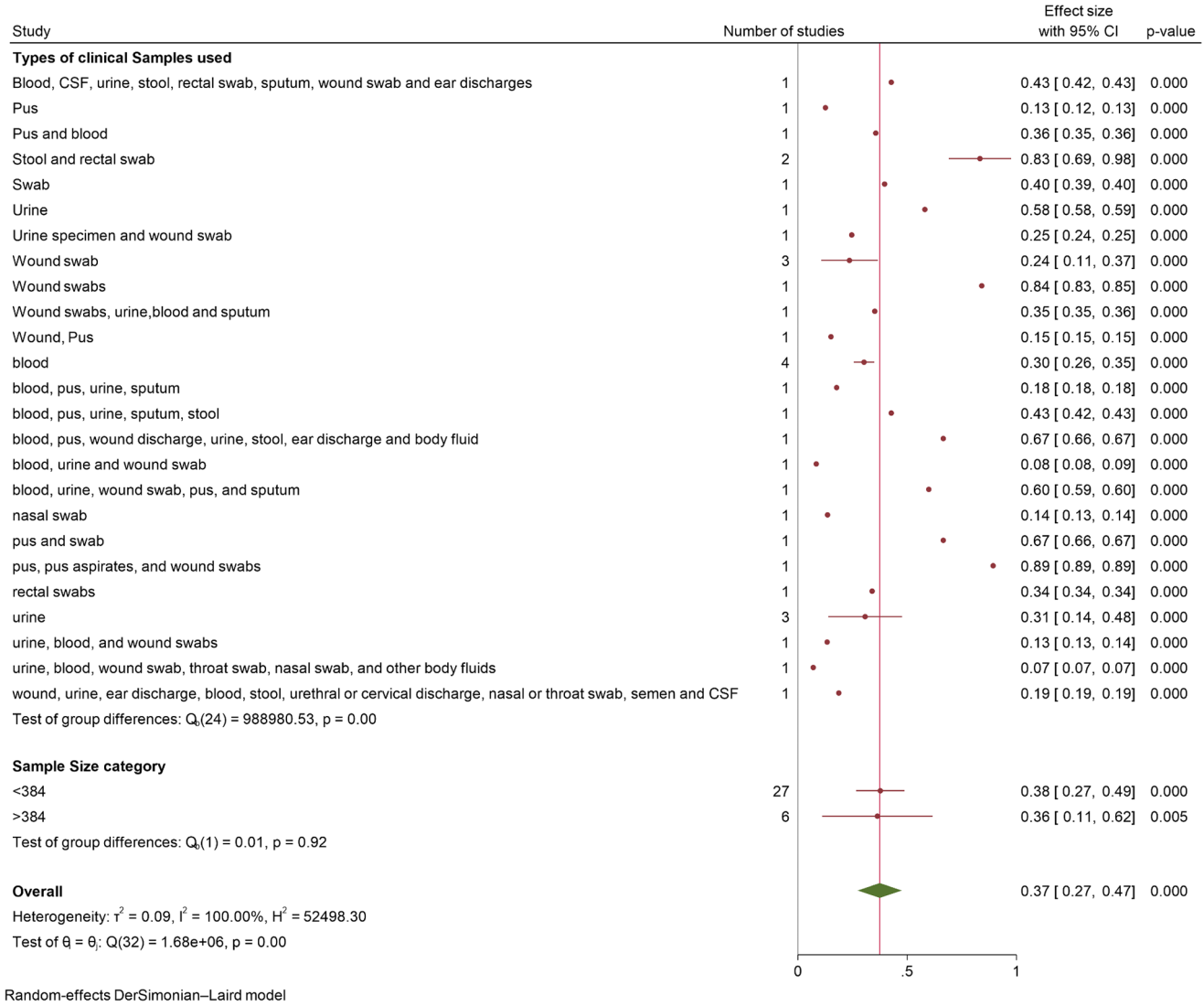

Fig. 6 Forest plot showing subgroup analysis of HCAIs type of clinical samples and sample size category

negative pathogens which was supported by previous finding reported from a previous systematic review in Africa [60]. The most common causative organisms were *E. coli*, *Klebsiella* species, *P. aeruginosa*, *Acinetobacter* species, and *Citrobacter* species [61, 65]. In addition to these pathogens *S. aureus* also the predominant gram-positive pathogen next to the above gram negatives. These pathogens are associated with nosocomial infection as a result of persisting in inanimate objects and environmental surfaces in the hospital or healthcare environments.

Based on the pooled analysis of adjusted odd ratio of studies, DM, comorbidities and/ or underlying diseases, contaminated wound, history of admission in ICU, and history of UTI were associated with HCAIs. According to the current systematic review and meta-analysis, patients with DM have a 5.97-times higher risk of developing HCAIs than people without diabetes. The impact of hyperglycaemia on immunological functioning may be the cause of this increased risk of infection. By impairing chemotaxis, adhesion, phagocytosis, the antioxidant system, humoral immunity, and lowering blood sugar levels, hyperglycaemia reduces the function of neutrophils and monocytes. It also lessens urine's antibacterial action. Additionally, DM patients are more likely to contract Staphylococcus and Group A&B Streptococcus infections. Additionally, elevated blood sugar levels promote the growth of bacteria and hasten the progression of diseases. Glycosuria also enhances bacterial growth and impair phagocytosis [69, 70]. Evidence therefore suggested that HbA1C 8% and perioperative blood sugar levels should be less than 200 mg/dl in order to maximize the care of patients with DM and limit the risk of complications [70].

We found that patients who have comorbidities and/ or underlying chronic diseases were 3.9 times more likely to

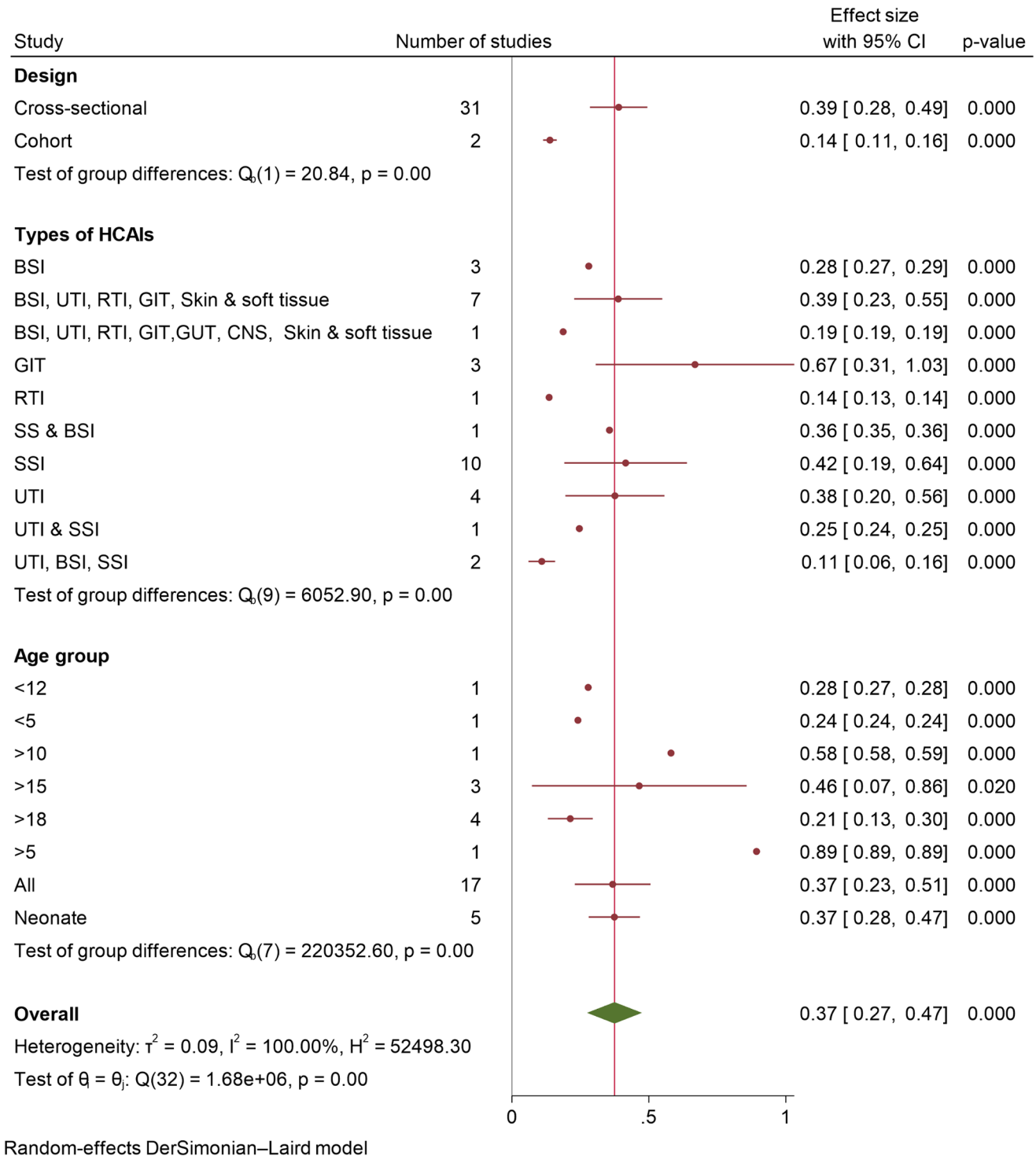

Fig. 7 Forest plot showing subgroup analysis of HCAIs by study design, types of HCAIs and age group

develop HCAIs than their counterparts. This might be due to the fact that frequent hospitalization is more common in patients with multiple comorbidities or those with complicated chronic illnesses which predispose such patients to an increased risk of HCAIs and colonization or infection with multidrug resistant pathogens. Thus, it is suggested that health care providers and policymakers need understandings of the exact mechanisms to effectively intervene against risk factors [71], and thereby to improve prevention and therapy of infections in people with chronic diseases. Moreover, patients with clean contaminated wound were

Table 3 Meta-regression analysis of potential covariates with magnitude of HCAIs in Ethiopia

Covariates	Coefficient	95% CI	R^2 (%)	*P*
Quality of studies	−0.0367722	−0.1956506 0.1221061	7.89	0.65
Organism type	0.0182399	−0.014825 0.0513048	15.15	0.280
Setting	−0.0187554	−0.0484732 0.0109624	13.17	0.216
Study population	0.0028674	−0.0314203 0.037155	3.83	0.87
Category of publication year	−0.2440298	−0.5222722 0.0342125	0.68	0.086
Condition of Patients (confirmed or suspected HCAIs)	0.0848743	−0.115028 0.2847766	6.20	0.405
Clinical sample type	−0.0082773	−0.0224203 0.0058656	5.3	0.351
Region	−0.0448894	−0.1138233 0.0240446	3.36	0.202
Total R-square			55.58	

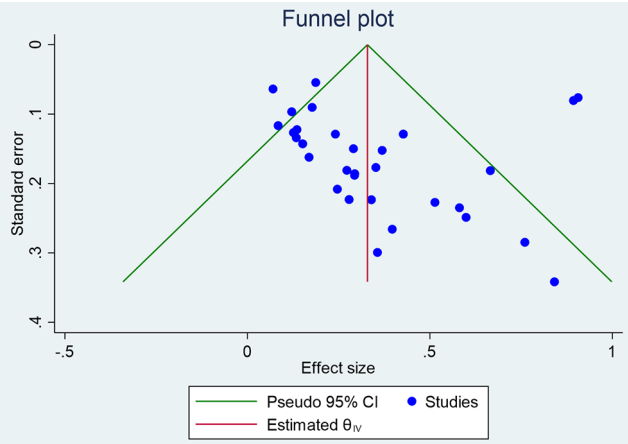

Fig. 8 Funnel plot for publication bias on study of the prevalence of HCAIs in Ethiopia

7.4 times more-likely to develop HCAIs than those who have clean wound.

The odds of HCAIs among patients who have a history of hospitalization in ICU was higher (OR: 2.93, 95% CI: 1.32–6.51%). This may be augmented by the severity of the disease among ICU patients. Likewise, highly invasive procedures such as intubation, peripheral, and central venous catheters are more common among ICU patients leading to increasing the risk of HCAI to higher [63]. Moreover, patients with a history of UTI had higher odds of developing HCAIs than their counter parts (OR: 2.39; 95% CI; 1.38–4.14%).

The clinical implication of this meta-analysis is that the high prevalence of multi-drug resistant health care

Table 4 Clinical related factors associated with HCAIs in Ethiopia

SN	Clinical predictors	Number of studies	Pooled OR (95% CI)	*P*-value	I^2 (*P*-value)
1	Comorbidities	8	3.91(2.22–6.90)	<0.001	68.65% (<0.001) *
2	Contaminated wound	3	7.44(2.17–25.44)	<0.001	85.58% (<0.001) *
3	Hospitalization in ICU	2	2.93(1.32–6.51)	0.001	67.39% (0.008) *
4	Catheterization	4	1.06(0.46–2.48)	0.89	84.05% (<0.001) *
5	length of hospital stays	4	1.17(0.2–6.98)	0.86	95.61% (<0.001) *
6	History of UTI	2	2.39(1.38–4.14)	<0.001	32.25 (0.22)
7	Length of surgery > 2 h	3	1.09(0.24–4.92)	0.91	94.49% (<0.001) *
8	Antibiotic use	3	1.19 (0.24–5.99)	0.83	92.24% (<0.001) *
9	Diabetes mellitus	4	5.97(2.26–15.76)	<0.001	66.33% (0.03) *

Keys: - *: Statistically significant; ICU: Intensive Care Unit; UTI: Urinary Tract Infection

associated bacterial infections among hospitalized patients should guide healthcare professionals to minimize the risk of HCAIs and emergence of drug resistant infections by providing guidance to the patient who undergone to surgery, give information about possible risk factors during routine patient care, and provide knowledge about wound care and indwelling of instruments. The Nurses' role is considered crucial in optimizing the healing outcomes through aseptic patient care; provision of explicit patient instructions on how to care for their wound, education and counselling and understanding of the patient's needs. In addition, identifying associated risk factors may help health care professionals treat infected patients during their clinical care. Furthermore, implementing infection prevention strategies tailored to high-risk groups could add practical value for healthcare practitioners and policymakers are also the clinical implications of this study findings.

As a limitation, the reviewed studies were highly heterogeneous reporting a wide range of pathogens, and studies were conducted with different sample sizes resulting high heterogeneity. Therefore, to limit the influence of the study heterogeneity, the random-effects model of DerSimonian and Laird was used, Galbraith plot, subgroup analyses, sensitivity analysis and meta-regression were performed but between study variability was not ruled-out. Likewise, only type of organism detected and the study setting were

maximally explaining the source of heterogeneity using meta-regression. Overall, only 55.58% of between study variance was explained by multiple meta-regression. Thus, the results should be interpreted with caution as the reviewed studies were heterogeneous.

6 Conclusion and Recommendation

According to this systematic review and meta-analysis, the pooled prevalence of health care associated bacterial infections have alarmingly increased and become a public health threat. Diabetes mellitus, comorbidities and/ or underlying diseases, contaminated wound, history of UTI and history of admission in ICU were the clinical predictors for the development of HCAIs. Effectively implementing personalized infection prevention and control approach which identifies patients at risk of HCAIs from the point of admission maximizes the potential for prevention of HCAIs as well as prescribing and using antibacterial agents against bacterial infections selectively based on antimicrobial sensitivity testing results and developing rational prescribing habits to minimize of the unwanted use of antibiotics might decrease selective pressure of resistant strains.

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Author Contributions AG conceived and designed the study. AG, AA, FY, SW and FB participated in article search, and data extraction. AG, AA and FB conduct a quality assessment of the included studies and perform the statistical analysis and interpretation of the data. AG drafts manuscript. AG, FY and SW check the validity and monitor the overall process. AA, AA and SW critically reviewed the manuscript. All the authors read and approved the final manuscript.

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Declarations

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Consent for Publication Not applicable.

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