BMC Public Health

RESEARCH

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Clinical and sociodemographic factors of diabetes mellitus among people living with HIV in Ethiopia: a systematic review and meta-analysis

Melsew Setegn Alie[1*], Gossa Fetene Abebe[2], Amanuel Adugna[2], Desalegn Girma[2], Yilkal Negesse[3] and Animut Alebel Ayalew[4,5]

Abstract

Background Chronic comorbidities such as diabetes mellitus are a growing concern for people living with HIV, particularly in low and middle-income countries where it is also highly prevalent. However, there is a lack of synthesized evidence on factors of diabetes among people living with HIV in Ethiopia. Therefore, this study aims to determine the clinical and sociodemographic factors of diabetes mellitus among people living with HIV.

Methods A comprehensive search was conducted from Scopus, PubMed/MEDLINE, Web of Science, Science Direct, and African Journal Online. This search adhered to the PRISMA 2020 guideline and was conducted as of July 18, 2024. The quality of included articles was assessed using the Newcastle-Ottawa scale. The R software with the Meta package was utilized for meta-analysis. The pooled estimations were performed using a random effects model. The pooled estimates with their corresponding 95% confidence intervals were presented using a forest plot.

Results Results from 12 studies indicated that the pooled prevalence of diabetes among people living with HIV was 8.0% (95% CI: 7.0, 9.0). Various factors were identified as factors of diabetes in this population. Older age, higher education level, body mass index(BMI) > 25 kg/m^2, longer duration of antiretroviral therapy (ART), hypertension, high levels of low-density lipoprotein (LDL) cholesterol, obesity, and high levels of triglycerides were significant factors of diabetes mellitus.

Conclusion The pooled prevalence of diabetes among people living with HIV is higher than the national prevalence. Older age, higher education level, BMI > 25 kg/m^2, longer duration on ART, hypertension, LDL cholesterol, obesity, and high levels of triglycerides were factors of diabetes. Interventions should prioritize older individuals and those with higher education levels who also have hypertension. By focusing on these specific groups, we can improve the management and prevention of diabetes among people living with HIV.

Keywords Diabetes mellitus, DM, Diabetes type 2, T2DM, Risk factor, Ethiopia

*Correspondence:
Melsew Setegn Alie
melsewsetegn2010@gmail.com

Full list of author information is available at the end of the article

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Introduction

By the end of 2023, nearly 39.9 million individuals were living with HIV globally [1], and over 1.5 million new cases of HIV were reported [2]. Of these, 65% were from sub-Saharan Africa (SSA). Despite the significant improvements in HIV-related morbidity and mortality with the introduction of highly active antiretroviral therapy (HAART), people living with HIV (PLHIV) remain at higher risk of developing co-morbidities, including diabetes mellitus [3–6]. Diabetes mellitus (DM) is a chronic metabolic disorder defined as a persistent high blood sugar [7]. The prevalence of DM among adults living with HIV who are on HAART varies across different regions. In Africa, the reported prevalence ranges from 2.1% to 25.5% [8]. The prevalence of diabetes among PLHIV was 14.9% in Zimbabwe [9], 4.5% in Malawi [10], 23.59% in South Africa [11], and 16.04% in Ethiopia [12]. In Ethiopia, the prevalence of diabetes mellitus among people living with HIV ranges from 2.09% to 56.4% [13, 14].

Diabetes related mortality of adults with HIV is almost three times that of adults without HIV [15]. In PLHIV, the risk of non-communicable disease increased due ageing process and the disease itself. HIV/AIDS treatment is also associated with metabolic disorders [16, 17]. In Ethiopia, the prevalence of diabetes mellitus has increased from time to time. The coexistence of two chronic illnesses is one of the healthcare challenges [18]. Ethiopia experienced an increase in the prevalence of DM along with HIV. Two of them (DM and HIV) go side by side in resource-limited countries like Ethiopia [19]. The diabetes management services are uneven, which contributes the public Health challenges [20].

Chronic illnesses such as diabetes, when combined with HIV infection, can significantly complicate the management of HIV. DM can leads to both macro complications, such as ischemic heart disease, cerebrovascular disease, and amputation, as well as micro complications [21–26]. Furthermore, this combination increases the risk of premature death, places a burden on family income, strains the healthcare system, and impacts national budgets [27, 28]. In 2019 alone, approximately 4.2 million individuals aged 20–79 died as a result of diabetes mellitus, accounting for 14.5% of global all-cause mortality. The financial impact of diabetes is also substantial, with health expenditures related to diabetes reaching at least USD 760 billion in 2019 [12, 29].

Multiple factors have been identified as contributors to the development of diabetes mellitus in individuals infected with HIV. These factors include gender, physical inactivity, smoking, alcohol use, family history of diabetes mellitus, CD4 count, viral load, body mass index, age, hepatitis C coinfection, inadequate diet, personal history of hypertension (HTN), and duration of HIV infection [30–33]. Furthermore, the use of specific medications as part of a combination HAART regimen has also been found to contribute to the onset of diabetes mellitus in HIV-infected individuals [34]. A meta-analysis study has shown that the risk of developing diabetes mellitus is approximately four times higher in HIV-infected patients compared to those who are not infected with HIV. This study also identified HAART as the primary determinant of diabetes mellitus in HIV-infected individuals [35]. A study conducted in Africa [36], and in Ethiopia [12], did not include recent research on the current situation of COVID-19, which has significantly impacted healthcare services. In addition, evidence on diabetes among people living with HIV increased; there is a consistent pattern and gaps in knowledge regarding clinical and sociodemographic factors of diabetes in this population, which provides a comprehensive synthesis of evidence [36]. Since there is no updated and recent systematic review and meta-analysis in Ethiopia, we conducted this review and included recent publication data for analysis. In Ethiopia, there is no systematic review and meta-analysis that assesses clinical and sociodemographic factors of diabetes mellitus among people living with HIV. Therefore, this study aimed to synthesise the pooled prevalence, clinical, and sociodemographic factors of diabetes mellitus among people living with HIV in Ethiopia.

Methods

Data sources and search strategy

This study adhered to the guidelines set forth by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [37]. We conducted a comprehensive literature search across several databases, including Scopus, PubMed/MEDLINE, Web of Science, Science Direct, and African Journal Online. Our search utilised a combination of keywords to identify publications discussing the prevalence of diabetes and its risk factors among PLHIV. The search terms included "diabetes," "T2DM," "diabetes mellitus," "DM," along with "risk factor," "associated factor," "determinants," "HIV," and "Ethiopia." Only observational studies conducted in Ethiopia were included in this systematic review and meta-analysis. Three authors (MSA, YN, and DG) independently screened the titles, abstracts, and full texts of the articles. In cases of disagreement, they engaged in discussions to reach a consensus. To ensure transparency and adherence to a standardized methodology, the researchers developed and registered a review protocol. The registration number for this systematic review and meta-analysis in PROSPERO is CRD42024572202.

Eligibility criteria

Inclusion criteria

Studies that report on the prevalence and factors of diabetes among PLHIV in Ethiopia, were included in our

research. Our research question was structured according to the PICO(S) format: Participants (P) were PLHIV, while the Intervention (I) and Comparison (C) components were not applicable. The Outcome (O) of interest was diabetes mellitus. We aimed to assess the prevalence of diabetes and its sociodemographic impact on PLHIV. For this systematic review and meta-analysis, we focused on observational studies published in English before July 2024.

Exclusion criteria

We excluded communications, reviews, commentaries, letters to the editor, and protocols from our analysis. Additionally, studies lacking analyzable raw data, those without clear outcome measurements, and qualitative studies were also excluded.

Study screening process

To avoid any duplicate files, we implemented a two-stage screening process. Initially, we evaluated the titles and abstracts, and then proceeded to conduct a thorough examination of the full-text articles. To ensure accuracy, two authors utilized the EndNote software to assess the potential relevance of each article for further review. This assessment was based on a predefined set of criteria for inclusion and exclusion. In situations where there were disagreements between the reviewers' evaluations, they were resolved through discussion and by seeking input from a third reviewer. To maintain a record for auditing purposes, electronic records were kept for both the studies included and those excluded, with clear explanations provided for any exclusions made.

Quality assessment and risk of bias

The potential bias in the study, a quality assessment checklist was utilized. The checklist, developed by Hoy and colleagues, consists of nine essential items that are crucial for evaluating the study's quality. These items include aspects such as the target population, sampling frame, sampling method, response rate, data collection procedures, study case definition, study instruments, and parameters for the numerator and denominator. Each item contributes to a maximum score of 9. Based on the scores obtained, the studies were categorized as having a high-risk (0–3), moderate-risk [4–6], or low-risk [7–9] of bias. Each study was evaluated independently, and the majority of them showed a low risk of bias. To ensure the reliability of the results, studies with a high risk of bias were excluded from the final analysis.

Data extraction

Data extraction was done using a Microsoft Excel template. The form was tested and revised iteratively as needed. Two authors, YN and DG, independently conducted the extraction. If there were any disagreements between the data extractors, the primary author, MS Alie, facilitated discussions to resolve them. The extracted descriptive variables covered different aspects, including the first author, region where the study was conducted, study design, study period, data collection method, sample size (PLHIV), prevalence of DM, response rate, mean CD4 count, mean duration of ART, BMI, age, diabetes diagnosis criteria, response rate, and adjusted odds ratio associated with diabetes comorbidity. For factors, the row data were extracted from regression table using a two-by-two table.

Data synthesis and analysis

We extracted data from various articles using Microsoft Excel version 2013. The, exported to R software version 4.3.2 for further analysis. The pooled prevalence was estimated using a random-effects meta-analyses model. Heterogeneity between included studies was evaluated using utilized I^2 statistics, where I^2 values of 25%, 50%, and 75% indicated low, medium, and high heterogeneity, respectively [38]. We also conducted subgroup analysis, bias assessment, sensitivity analysis, and heterogeneity analysis. To assess publication bias, we examined the distribution of studies in a funnel plot. Additionally, we performed leave-one-out sensitivity analysis to assess the influence of individual studies on the overall effect. Our results were presented using the logit transform of the individual studies, accompanied by their respective 95% confidence intervals, and presented in tables and figures.

Sensitivity analyses

A thorough sensitivity analysis was conducted to assess how individual studies affected the overall estimation of the prevalence of diabetes among people living with HIV. Each study was methodically omitted, and the resulting impact on the estimate was carefully examined.

Results

Search results and eligible research reports

A comprehensive search resulted in the identification of 2,809 records. To ensure accuracy, 2,674 duplicate records were removed using the EndNote application. In the second stage, an additional 154 records that did not meet the eligibility criteria were removed, as they focused on populations outside the category of people living with HIV. This left us with 23 records for further assessment. Upon closer examination, 8 articles were excluded as they did not align with the study outcome. These articles included review articles, qualitative studies, and clinical studies. The remaining 15 articles underwent a thorough screening based on their full text. Three articles were excluded due to unrelated findings and unclear outcome

measurements, leaving us with 12 articles for the final systematic review and meta-analysis (Fig. 1).

Study characteristics

Finally, 12 studies conducted in different regions of Ethiopia, focusing on the prevalence and risk factors for diabetes among PLHIV were included. The studies were distributed as follows: two in the Oromia region, four in Amhara, three in the Southern Nations, Nationalities, and People Region (SNNPR), two in Harari, and one in Addis Ababa. The sample sizes in these studies varied, ranging from 176 to 520 participants, resulting in a total of 4,595 individuals included in the analysis. The years of publication ranged from 2012 to 2024. Specifically, 2 studies were conducted in the Oromia region, 4 in the Amhara region, 3 in SNNPR, and 1 in Addis Ababa. The remaining studies were conducted in other regions of the country (Table 1).

Quality assessment, risk of bias, and sensitivity analysis

The quality and potential bias of the studies were assessed using the Newcastle-Ottawa Scale (NOS), which considers three important factors: selection, comparability, and outcome. To maintain accuracy, one author conducted the evaluation, and it was independently reviewed by another author. The NOS assigns a maximum of 9 points, with scores above 7 indicating a minimal risk of bias. According to the NOS evaluation (S1 file), the studies included in this systematic review and meta-analysis exhibited a low risk of bias.

The exclusion of any single study did not have a significant effect on the pooled prevalence estimate in this systematic review and meta-analysis. Furthermore, none of the studies fell outside the confidence interval's lower and upper boundaries. These findings indicate that the collective results of the studies remained strong and consistent, reinforcing the reliability of the overall prevalence estimate.

S1 file: the Newcastle-Ottawa quality assessment evaluation result for this systematic review and meta-analysis.

Pooled prevalence of diabetes among PLHIV

The results of the study revealed that the overall prevalence of diabetes mellitus among adult individuals with HIV in Ethiopia was 8.0% (95% CI [7.0–9.0]). The heterogeneity analysis showed that 38% and a p-value of 0.09 (Fig. 2).

Subgroup analysis

A subgroup analysis was conducted to investigate the observed differences in the study. This analysis specifically focused on the study region within the country. The findings regarding the subgroup analysis of diabetes mellitus among people living with HIV revealed that

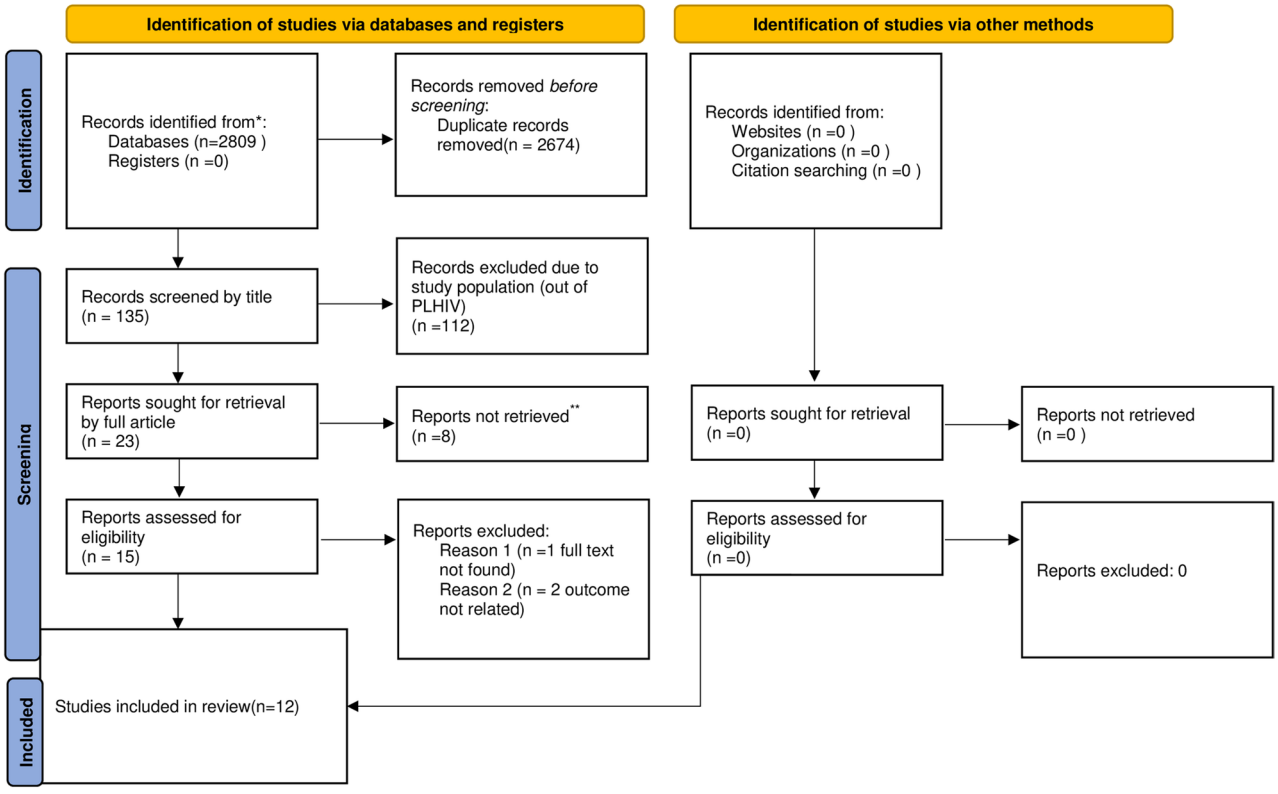


Fig. 1 The PRISMA flowchart shows the study selection. **Reasons of retrieval protocol, review, editorial letter qualitative study, and unclear outcome

Table 1 Descriptive presentation of the study included in the systematic review and meta-analysis among people living with HIV in Ethiopia

Author(years)	Region	sample size	study setting	Study period	sampling Method	study design	number of case	prevalence
Gebrie et al. (2020) [39]	Amhara	407	Hospital based	February 2019 and April 2019.	simple random sampling	Cross sectional	36	8.8% (95% CI 6.05, 11.55)
Tegene et al. (2023) [40]	SNNPR	377	Hospital based	2019 to 2021	simple random sampling	Cohort	14	4%
Eshete et al. (2015) [41]	Oromia	393	Hospital based	April to May 2014	convenient Sampling	Cross sectional	25	6.40%
Fiseha et al. (2019) [14]	Amhara	408	Hospital based	January to March 30, 2018	convenient Sampling	Cross sectional	36	8.8%(6.4% to 11.8%)
Abebe et al. (2016) [42]	Amhara	462	Hospital based	December 2013 to the end of February2014	systematic sampling	Cross sectional	37	8.0%(5.5–10.5)
Getahun et al. (2020) [43]	Amhara	547	Hospital based	March 1 to 31,2018	simple random sampling	Cross sectional	47	8.60%
Ataro et al. (2018) [44]	Harari	425	Hospital based	February and April 2017.	convenient Sampling	Cross sectional	30	7.1%(4.9–9.9)
Duguma et al. (2020) [6]	Oromia	271	Hospital based	May to July 30, 2018.	convenient Sampling	Cross sectional	31	11.40%
Sachithananthan et al. (2012) [45]	SNNPR	176	Hospital based	December 1 st, 2009 - January 30th, 2010	Simple random sampling	Cross sectional	14	8%
Badacho et al. (2023) [46]	SNNPR	520	Hospital based	January and June 2022	convenient Sampling	Cross sectional	36	6.9%(4.8–9.2)
Shimels et al. (2024) [47]	Addis Ababa	185	Hospital based	1 February to 30 March 2022	simple random sampling	Retrospective cohort	13	7.0%(3.8–10.3)
Teka et al. (2018) [48]	Harari	424	Hospital based	March 10 to April 20, 2017	Simple random sampling	Cross sectional	28	6.60%

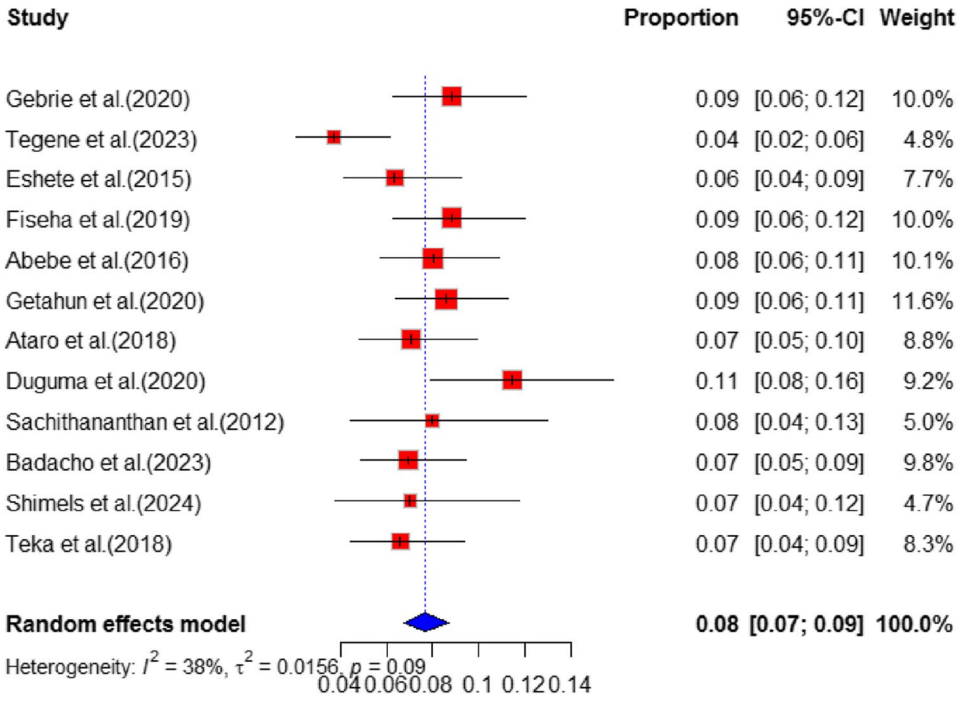


Fig. 2 Shows the forest plot of the pooled prevalence of diabetes mellitus among people living with HIV

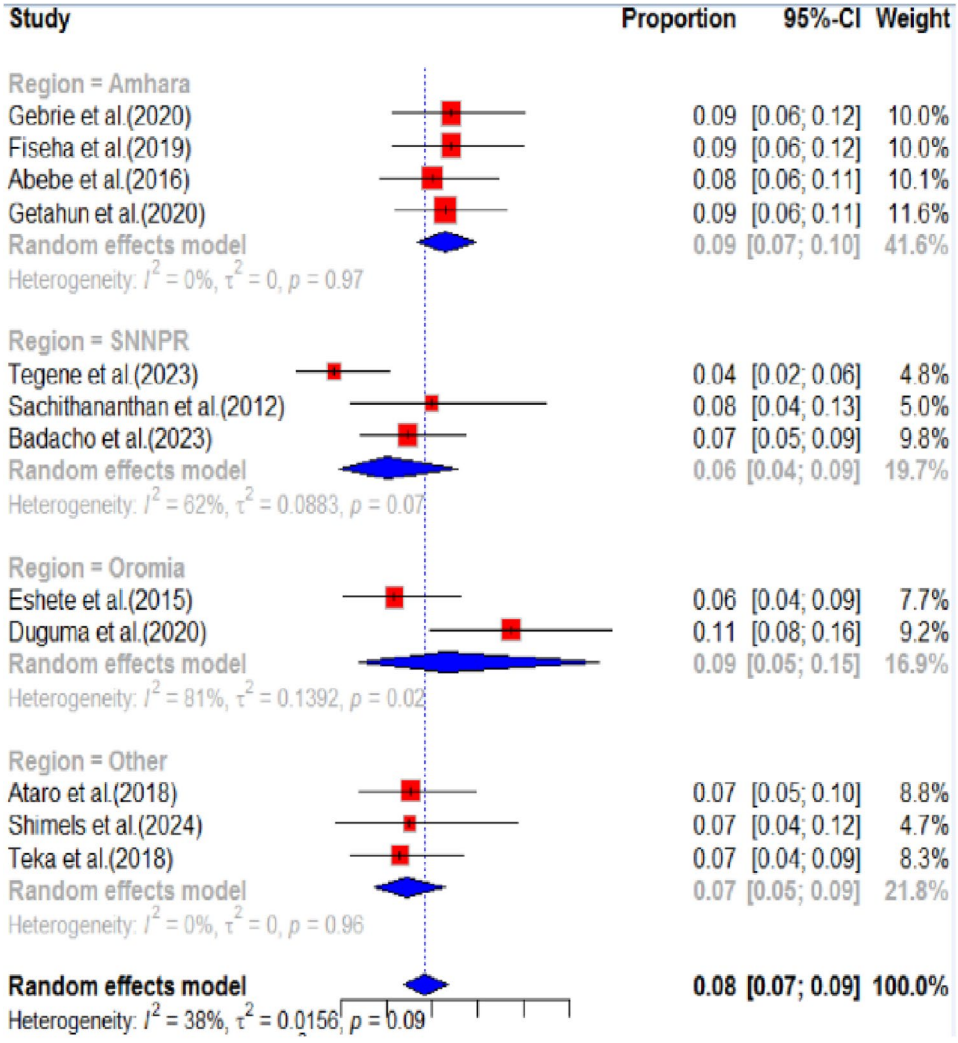


Fig. 3 Shows subgroup analysis by region for diabetes mellitus among HIV positive adults in Ethiopia

Fig. 3 Shows subgroup analysis by region for diabetes mellitus among people living with HIV in Ethiopia

Table 2 Meta-regression analysis of diabetes mellitus among PLHIV clients in Ethiopia

Heterogeneity source	Estimate	Se	Z value	*P*-value	CI	I^2
Sample size	−0.0002	0.0006	−0.3772	0.7060	−0.0015-0.0010	38.36%
Publication year	−0.0107	0.0228	−0.4666	0.6408	−0.0554-0.0341	40.33%

the highest prevalence of diabetes among PLHIV was observed in the Amhara and Oromia regions, which showed that the prevalence was 9.0% (95%CI: 7.0–10.0), and 9.0% (95%CI: 5.0–15.0), respectively. In the Amhara region, four studies conducted between 2016 and 2020 were included in the analysis. The SNNPR region had a prevalence of 6.0% (95% CI: 4.0%–9.0%), and three studies conducted between 2013 and 2023 were included in the analysis for this region (Fig. 3).

Meta-regression and sensitivity analysis

A meta-regression analysis was conducted to investigate the factors that may contribute to the variation in the estimated prevalence of diabetes mellitus among PLHIV. Specifically, the study examined the relationship between sample size and publication years as potential sources of heterogeneity. The results indicated that the sample size of diabetes mellitus was not a significant source of heterogeneity, and neither variable contributed to heterogeneity (Table 2). Since neither variable showed heterogeneity, further analysis is not necessary. To further explore the impact of individual studies on the overall

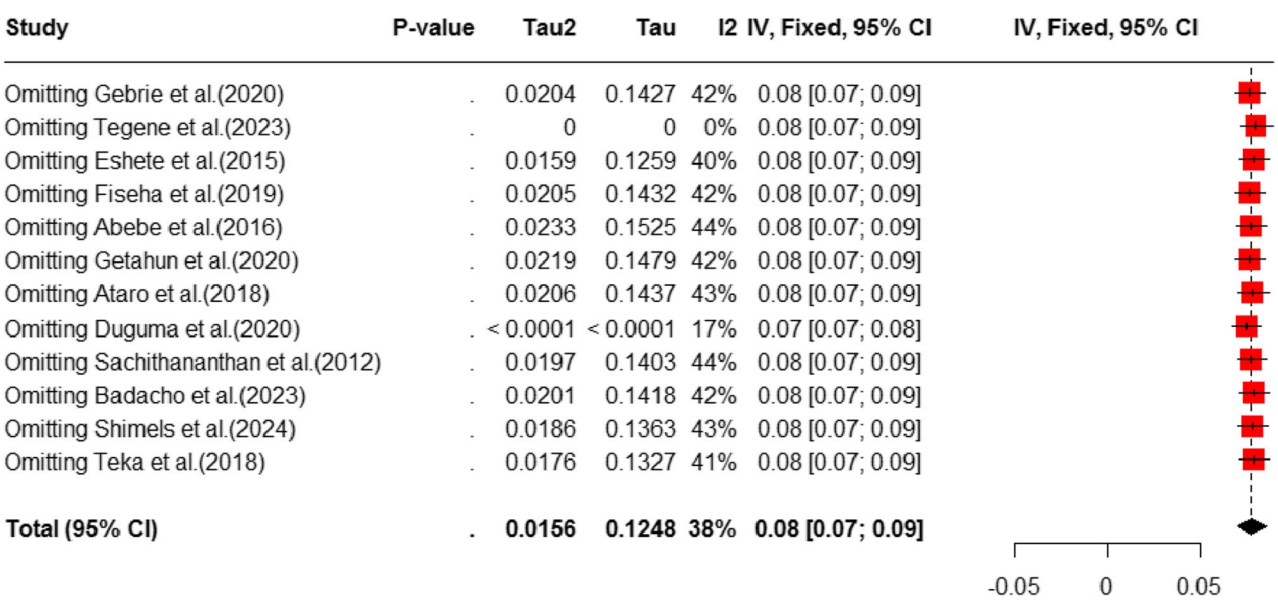


Fig. 4 Shows the sensitivity analysis of leave in and leave out research of diabetes research

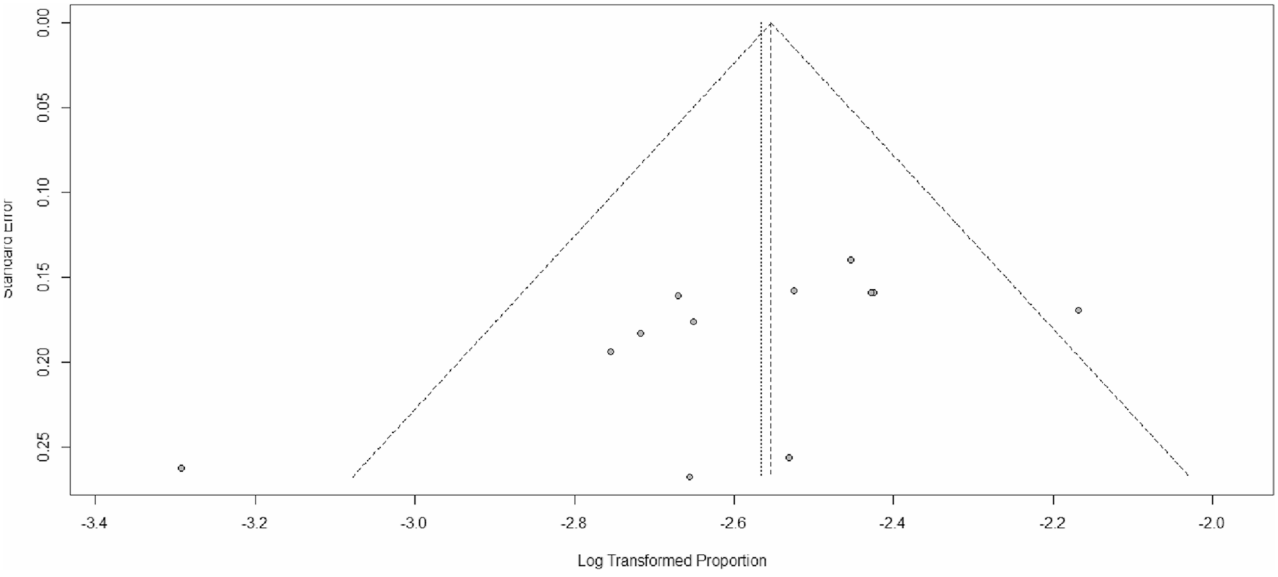


Fig. 5 Shows the funnel plot of diabetes mellitus among PLHIV in Ethiopia

pooled estimate of diabetes mellitus among PLHIV, a sensitivity analysis was performed. Fig. 4 demonstrates that all studies made nearly equal contributions to the pooled result of the study.

Publication bias

To assess publication bias in our study on diabetes mellitus among people living with HIV, we visually examined a funnel plot. The analysis of the funnel plot revealed an asymmetric distribution, indicating the absence of visible publication bias. Furthermore, we conducted Egger's test, which yielded a non-significant result. The bias estimate was calculated as −3.4835 with a standard error (SE) of 1.6645. Based on these findings, we decided not to perform a trim and fill analysis for further assessment of publication bias. You can refer to Fig. 5 below to view the funnel plot representation in our study.

Association between sociodemographic and clinical factors of diabetes among PLHIV in Ethiopia

A systematic review and meta-analysis were conducted to examine the relationship between sociodemographic factors, lipid profile, and the factors of diabetes among PLHIV. The study aimed to determine the association between clinical and sociodemographic factors and diabetes mellitus among PLHIV. Four studies were included

in the meta-analysis to investigate the link between age and diabetes mellitus. The combined data from these studies revealed that PLHIV aged over 45 years who were receiving HAART were 3.33 times more likely to develop factors of diabetes mellitus compared to those in younger age groups (AOR = 3.329, 95% CI: 2.09, 5.51, I2 = 22%, $P = 0.28$).

The association between education and diabetes was assessed by pooling two studies. The findings indicated that PLHIV who attended college or above were 10.43 times more likely to have diabetes compared to individuals with lower educational status (AOR = 10.43, 95% CI: 3.72, 29.25, I2 = 0%, $P = 0.85$). Furthermore, BMI was identified as one of the factors of diabetes among PLHIV in Ethiopia. Three studies were involved in this systematic review and meta-analysis, and the results showed that HIV-positive adults with a BMI greater than 25 were 5 times more likely to have diabetes compared to individuals with a lower BMI (AOR = 5.00, 95% CI: 2.73, 9.18, I2 = 0%, $P = 0.58$).

According to the systematic review conducted, several clinical factors were examined in addition to sociodemographic factors to determine their association with diabetes. The findings revealed that hypertension, long duration of HAART, duration of ART exceeding 10 years, high levels of triglycerides, obesity, and low-density lipoprotein were identified as factors of diabetes. To specifically investigate the relationship between hypertension and risk of diabetes among people living with HIV, six articles from various regions of the country were included. The results indicated that individuals with hypertension were 4.73 times more likely to having diabetes mellitus compared to non-hypertensive individuals with HIV (AOR = 4.73, 95% CI: 2.69–8.31, I2 = 55%, $P = 0.05$). These findings emphasize the importance of considering clinical factors, such as hypertension, in assessing the risk of diabetes among individuals living with HIV.

In a meta-analysis examining the association between DM and triglyceride levels among HIV patients on HAART, two studies were selected. The pooled result of the analysis revealed a statistically significant association, indicating that a high level of triglycerides is linked to the prevalence of DM among these patients [AOR) = 2.56, 95%CI): 1.22, 5.36, I2 = 0%, $p = 0.88$]. Similarly, to assess the association between LDL and diabetes mellitus among HIV patients on HAART, three studies were included in the meta-analysis. The findings from the meta-analysis, using a fixed-effect model, demonstrated that HIV patients on HAART with abnormal LDL levels were 5.84 times more likely to have diabetes mellitus compared to those with normal LDL levels [PAOR = 5.84, (95% CI: 3.86, 8.84), I2 = 0.0%, $p = 0.77$].

Furthermore, the systematic review and meta-analysis also explored the association between obesity and diabetes among people living with HIV. The pooled result from three studies indicated a significant association between obesity and the presence of diabetes in this population. The meta-analysis, utilizing a fixed-effect model, showed that HIV patients on HAART who were obese had a 4.58 times higher likelihood of having diabetes mellitus compared to patients who were not obese [AOR = 4.58, (95% CI: 1.93, 10.84), I2 = 0.0%, $p = 0.63$] (Table 3). These findings highlight the importance of considering triglyceride levels, LDL levels, and obesity as potential risk factors for diabetes mellitus in HIV patients receiving HAART.

Discussion

The prevalence of diabetes is experiencing a concerning surge in low and middle-income countries. Moreover, the burden of diabetes among HIV patients receiving Highly Active Antiretroviral Therapy (HAART) is alarmingly on the rise, particularly in lower and middle-income countries [39, 49]. According to our research, we have found that the overall prevalence of diabetes among people living with HIV is 8.0% (95% CI [7.0–9.0]). This figure is lower compared to the prevalence rates reported in Ethiopia (16.04%) [12], Tanzania (17%) [50], Senegal (14.5%) [51], Nigeria (12%) [52], and among African Americans (12%) [53]. The observed discrepancy can be attributed to variations in the sociodemographic characteristics of the study participants and the diverse implementation of interventions across the country. Another possible explanation for this difference could be the varying program designs focusing on chronic illnesses such as diabetes and lifestyle interventions within the country. The comprehensive global report on type 2 DM highlights the lifestyle determinants associated with DM among PLHIV. These determinants encompass various lifestyle factors that contribute to the onset of type 2 DM. They encompass unhealthy dietary patterns, lack of physical activity, tobacco use, alcohol consumption, as well as factors such as ethnicity and age [54].

This systematic review higher than the study conducted in South Africa [55], Malawi (4.1%) [6], Taiwan (7.1%) [4], Denmark (3%) [56], Canada is (4.6%) [56] and WHO region countries (4.9%) [57]. The difference in healthcare outcomes can be attributed to the implementation of programs focused on preventing chronic illnesses and improving primary healthcare services in the country. Furthermore, the use of digital health platforms has the potential to significantly improve the management of chronic diseases at a larger scale within healthcare systems [58]. This implies that strong primary health care implementation and digitalizing the chronic illness program could highly improve the incidence of diabetes in the countries.

Table 3 Factors associated with diabetes mellitus among people living with HIV in Ethiopia

Variables	Number of studies	Pooled AOR (95%CI)	Heterogeneity(I^2,*p*-value)
Age > 45 years	Fiseha et al. (2019) [14]	3.329(2.09–5.51)	I^2 = 22%, *P* = 0.28
	Sachithananthan et al. (2012) [45]		
	Badacho et al. (2023) [46]		
	Teka et al. (2018) [48]		
College and above education	Gebrie et al. (2020) [39]	10.43(3.72–29.25)	I^2 = 0%, *P* = 0.85
	Abebe et al. (2016) [42]		
BMI > 25	Getahun et al. (2020) [43]	5.00(2.73–9.18)	I^2 = 0%, *P* = 0.58
	Ataro et al. (2018) [44]		
	Badacho et al. (2023) [46]		
Longer duration on of HAART	Eshete et al. (2015) [41]	7.47(1.92–28.99)	I^2 = 67%, *P* = 0.05
	Fiseha et al. (2019) [14]		
	Duguma et al. (2020) [6]		
Duration of ART > 10 years	Getahun et al. (2020) [43]	3.94(1.96–7.89)	I^2 = 73%, *P* = 0.02
	Badacho et al. (2023) [46]		
	Teka et al. (2018) [48]		
Hypertension	Eshete et al. (2015) [41]	POR = 4.73(2.69–8.31)	I^2 = 55%, *P* = 0.05
	Fiseha et al. (2019) [14]		
	Abebe et al. (2016) [42]		
	Ataro et al. (2018) [44]		
	Badacho et al. (2023) [46]		
	Teka et al. (2018) [48]		
Hyper triglyceride	Abebe et al. (2016) [42]	2.56(1.22–5.36)	I^2 = 0%, *P* = 0.88
	Duguma et al. (2020) [6]		
LDL	Eshete et al. (2015) [41]	5.84(3.86–8.84)	I^2 = 0%, *P* = 0.77
	Duguma et al. (2020) [6]		
	Teka et al. (2018) [48]		
Obesity	Abebe et al. (2016) [42]	4.58(1.93–10.84)	I^2 = 0%, *P* = 0.63
	Duguma et al. (2020) [6]		
	Badacho et al. (2023) [46]		
Triglyceride	Gebrie et al. (2020) [39]	3.70(0.83–16.50)	I^2 = 96%, *P* < 0.01
	Ataro et al.(2018) [44]		
	Teka et al. (2018) [48]		

In this systematic review, we have identified several factors that are associated with an increased risk of diabetes mellitus among people living with HIV in Ethiopia. These factors include older age (greater than 45 years), higher education level (college and above), higher body mass index (BMI), longer duration of antiretroviral therapy (ART), hypertension, high levels of low-density lipoprotein (LDL) cholesterol, obesity, and high levels of triglycerides. Our findings support the well-known fact that older age is a risk factor for diabetes. This finding is consistent with studies conducted in Senegal [59], Ethiopia [12], Botswana [60], Swiss [61], Asia-Pacific region study [62], France [63], Vietnam [64], and Brazil [65], which also found that older age is associated with an increased risk of diabetes among people living with HIV. One possible explanation for this association is that advanced age can lead to impaired pancreatic islet cell function, resulting in decreased insulin secretion. Additionally, as we age, our cells tend to become more resistant to the effects of insulin [66, 67]. The screening can help identify individuals who may be at a higher risk of diabetes and allow for early intervention and management [68].

Regarding the meta-analysis of sociodemographic factors of diabetes mellitus among people living with HIV, individuals attended college and above education were more likely associated with diabetes. This finding is consistent with the study conducted in study conducted in Ethiopia [12], Ghana [69], Mexico [70], low and middle income countries [71], and America [72]. While this finding is contrary with the study conducted in America and India [73]. The possible justification of this discrepancy could be due to variation in sampling, or methods used to assess education and diabetes. In addition this variation is due to difference in study area since the current study conducted in low income country. The study examines the implications of nutrition and obesity transition within low- and middle-income countries (LMICs) [74–76]. It proposes five stages of this transition, ranging from lean societies with hunter-gatherer lifestyles to industrialized societies with sedentary behavior and high

consumption of energy-dense foods, leading to obesity and diabetes. The fifth stage, observed in countries with higher economic growth, involves intentional reductions in sedentary behavior and the adoption of healthier eating habits. The study suggests that the analyzed countries may be in an advanced stage of the nutrition transition, but the socioeconomic gradient of diabetes risk has not yet reversed. As LMICs continue to develop, the burden of diabetes may eventually resemble that of high-income countries, emphasizing the need to address socioeconomic disparities in diabetes prevention and management [77]. This implies country sociodemographic issues and industrialization were highly influence the feeding practice of the individuals.

Regarding meta-analysis associated factors individuals living with HIV whose BMI > 25 kg/m^2 were more likely associated with diabetes as compared with normal body mass index individuals. This finding comparable with Asia-pacific study [62], Senegal, London [78], France [63], and Vietnam [64].

In this systematic review and meta-analysis the clinical factors were identified as associated factors of diabetes mellitus among people living with HIV. Based on this systematic review and meta-analysis the individuals developed hyper triglyceride were higher risk of diabetes as compared with the normal triglyceride level. This finding is consistent with the study conducted Botswana [60], and Ethiopia [6]. One possible explanation for the link between body mass index and type 2 diabetes is that having a higher body mass index (BMI) can cause cells in the body to become resistant to insulin [79, 80]. To prevent and delay the onset of diabetes, the World Health Organization (WHO) recommends adopting healthy lifestyle habits, such as maintaining a healthy weight [81]. This suggests that policies aimed at promoting healthy weight and physical activity can have a significant impact on the incidence of diabetes.

One of the clinical factors of diabetes mellitus among people living with HIV is the level of LDL-C (low-density lipoprotein cholesterol), which has been consistently observed in studies conducted in Botswana [60] and Ethiopia [6]. There is evidence suggesting that excessive circulating free fatty acids and protein-bound lipids contribute to the factors of other metabolic abnormalities. Furthermore, persistently high serum lipid levels have been linked to the development of steatohepatitis in people living with HIV. Additional deposits of lipids in unusual locations and glucose intolerance [82–84] may also accompany this condition. Consequently, these factors associated with diabetes among individuals living with HIV in Ethiopia in people living with HIV. According to a recent meta-analysis, it has been found that obesity is a significant predictor of diabetes mellitus among people living with HIV. This finding is consistent with previous studies conducted in countries such as Switzerland [61], Ethiopia [6, 85], Zimbabwe [9], and Brazil [86], which have also shown that obesity is associated with diabetes mellitus in this population. The possible reason behind this association is that obesity can increase insulin resistance in the body, leading to the factors of diabetes mellitus.

According to this review, individuals with hypertension have a higher likelihood of having diabetes mellitus compared to those without hypertension. This finding aligns with similar studies conducted in the Asia-Pacific study [62] and London [78], which also found that hypertension associated factors of diabetes mellitus in individuals living with HIV. The disturbance of carbohydrate metabolism in hypertensive patients may contribute to the occurrence of diabetes [87, 88]. One possible explanation is that hypertensive patients often experience insulin resistance, making them more susceptible to having diabetes. Hypertension is a significant risk factor for diabetes, leading to vascular complications characterized by vascular dysfunction and injury [89]. This finding suggests that not only lifestyle interventions but also appropriate management and monitoring of hypertension could help reduce the incidence of diabetes among people living with HIV in the country.

In our study, we found a strong association between abnormal triglyceride levels and diabetes mellitus in individuals living with HIV. This finding aligns with previous research conducted in Malaysia [90], Nigeria [91], Australia [92], and Brazil [86], which also demonstrated a link between abnormal triglyceride levels and the associated factors of diabetes in people living with HIV. The underlying mechanism behind this association is believed to involve increased free fatty acid flux caused by insulin resistance, which is further exacerbated by elevated levels of inflammatory adipokines [93]. These findings highlight the importance of early screening and monitoring of cholesterol levels in individuals living with HIV, as it may help reduce the incidence of diabetes.

In this meta-analysis longer duration of ART and duration of ART longer than 10 years were the factors of diabetes mellitus among PLHIV which is consistent with the study conducted in Ethiopia [46], Vancouver, British Columbia [94], America [31], and Mhlanga et al. [95] which indicated that longer duration on ART had its own influence on diabetes mellitus associated factors of people living HIV. The possible justification for this could be that during a period when individuals living with HIV (PLWH) were exposed to older ART medications with notable metabolic side effects, a significant number of new cases of DM were diagnosed. This supports previous research and suggests a potential link to the use of outdated nucleoside reverse transcriptase inhibitors (NRTIs) such as zidovudine and stavudine, which can contribute

to insulin resistance [34, 96–98]. Patients receiving these older NRTIs may experience increased breakdown of fat, leading to higher levels of circulating free fatty acids that promote insulin resistance in the liver and muscles. Additionally, emerging clinical evidence indicates a direct impact of thymidine analogue NRTIs on insulin resistance. Various mechanisms have been proposed to explain how protease inhibitors (PIs) may contribute to insulin resistance, including their effect on the glucose transporter GLUT4 and the reduction of insulin sensitivity. It is believed that the acute inhibition of the GLUT4 transporter, which plays a crucial role in glucose disposal, contributes to the initial stages of PI-associated insulin resistance [99–102]. In addition, chronic inflammation could contribute for the occurrence of diabetes. These findings highlight the importance of paying attention to and conducting early screening among individuals living with HIV. Early diagnosis and prevention of complications can be highly effective in this population segment.

Strengths and limitations

This study has successfully synthesized national evidence on the prevalence of DM among people living with HIV in Ethiopia, a vulnerable population for metabolic disorders. However, it is important to acknowledge the limitations of the study and consider them in future research. The primary limitation was the lack of primary studies from five regions in the country: Gambela, Somali, Afar, Dire Dawa, and Benishangul Gumuz. Furthermore, some of the primary studies accessed from other regions had smaller sample sizes. The use of the random effects model may have overestimated the true magnitude of DM among people living with HIV. Additionally, all studies included in the analysis were cross-sectional in design, which limits the ability to establish cause-and-effect relationships. Therefore, readers must interpret and use these findings with caution, taking into account the inherent limitations of the primary studies and the current analysis. Despite these limitations, this meta-analysis has identified areas for improvement in future studies. When we pooled some factors, we included only two studies, which may lower or overestimate the interpretation.

Conclusion

Diabetes mellitus is becoming more common among people living with HIV (PLWH) and significantly contributes to the overall disease burden experienced by these patients. The prevalence of diabetes among PLWH is higher than the national average. Several factors have been identified as factors of diabetes in PLWH, including older age (45 years and above), higher education level (college and above), higher body mass index (BMI), longer duration of antiretroviral therapy (ART), hypertension, high levels of low-density lipoprotein (LDL) cholesterol, obesity, and high levels of triglycerides. Clinical and sociodemographic factors greatly influence the incidence of diabetes in this population. Healthcare professionals must pay attention to older individuals with hypertension and conduct early screening for diabetes to detect it in its early stages. Regular monitoring and follow-up of cholesterol levels in individuals with HIV are recommended to reduce the incidence of diabetes. Enhanced screening for diabetes risk among PLWH should be comprehensive, taking into account a wide range of risk factors that affect this population, both conventional and HIV-specific. Interventions targeting these risk factors are necessary. It is also important to consider selecting antiretroviral medications that have minimal impact on insulin resistance in individuals with dysglycemia or significant risk factors. Additionally, proactive lifestyle management should be implemented to address the increased risk of diabetes associated with weight gain following the initiation of highly active antiretroviral therapy. Furthermore, it is crucial to determine whether diet and lifestyle interventions that effectively address diabetes risk factors in the general population, such as reducing blood pressure and hepatic steatosis, are also effective in people living with HIV.

Abbreviations

ART	Antiretroviral Treatment
AOR	Adjusted Odds Ratio
BMI	Body mass index
CI	Confidence Interval
DM	Diabetes Mellitus
HAART	Highly Active Antiretroviral Therapy
HIV/AIDS	Human immunodeficiency virus acquired immune deficiency syndrome
HTN	Hypertension
LDL	Low-Density Lipoprotein
LMIC	Lower and middle-income countries
NRTIs	Reverse Transcriptase Inhibitors
NOS	Newcastle-Ottawa Scale
PLHIV	People living with HIV
PIs	Protease Inhibitors
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SE	Standard Error
SNNPR	Southern Nation Nationality Peoples Region
SSA	Sub-Saharan Africa
T2DM	Type 2 Diabetes Mellitus
USD	United States Dollar
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-026-26338-z.

Supplementary Material 1.

Supplementary Material 2.

Protocol and registration

This review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta- Analysis guideline. The Prospero registration number for this study was CRD42024572202.

Authors' contributions
MA was comprehended and design the conception of the study. All authors (MA, AA, YN, GA, DG, and AN) contributed to the data extraction, analysis, interpretation of the result, and drafting of the article. AA revised and edited the final manuscript. All authors participated fully in revising the article, have agreed on the journal to which the article will be sent for publication, gave final approval of the version to be published, and agreed to take responsibility for all aspects of the work.

Funding
The authors did not receive any specific fund for this research.

Data availability
All necessary data included in the manuscript.

Declarations

Ethical approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Public Health, School of Public Health, College of Medicine and Health Science, Mizan-Tepi University, Mizan-Aman, Ethiopia
[2]Department of Midwifery, College of Medicine and Health Science, Mizan-Tepi University, Mizan-Aman, Ethiopia
[3]Department of Public Health, College of Medicine and Health Science, Debre Markos University, Gojjam, Ethiopia
[4]Australasian Health Outcomes Consortium, Faculty of Science, Medicine and Health, University of Wollongong, Wollongong, NSW, Australia
[5]School of Public Health, Faculty of Health, University of Technology Sydney, Ultimo, NSW, Australia

Received: 5 October 2024 / Accepted: 13 January 2026
Published online: 07 February 2026

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