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Smoking Status and Risk of Opportunistic Infections among Individuals Living with HIV: A Meta-Analysis

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ABSTRACT

Opportunistic infections (OIs) remain a major cause of morbidity and mortality in people living with HIV/AIDS (PLWHA). Smoking may impair immune system function and increase susceptibility to infection. However, its association with OIs in PLWHA remains understudied. This systematic review and meta-analysis aimed to evaluate the association between smoking status and OIs among PLWHA. Relevant research reports were identified through searches of Google Scholar, PubMed, and ScienceDirect. English-language studies published between 2011 and 2021 from various countries, including Korea, Ethiopia, and Turkey, were included in the analysis. The pooled estimate was calculated using a fixed-effects model and expressed as an odds ratio (OR) with 95% confidence intervals (CI). Six observational studies examining the association between smoking status and the incidence of OIs in PLWHA were analyzed in this meta-analysis. The results showed that smoking significantly increased the risk of OIs with a pooled OR of 1.76 (95% CI: 1.27–2.45). No significant heterogeneity was found between studies (I^2=0%; p=0.86). A study by Kim et al. (2016) in Korea reported the highest OR of 2.27 (95% CI: 1.22–4.22), while a study by Wachamo et al. (2020) in Ethiopia showed the lowest OR of 1.03 (95% CI: 0.28–3.79). The most common OI among PLWHA was candidiasis/oral candidiasis with a prevalence of 28.8%. smoking-cessation interventions should be integrated into HIV care to reduce OI-related morbidity and mortality.

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Introduction

Human Immunodeficiency Virus (HIV) remains a major global health concern, particularly because of the continued burden of opportunistic infections (OIs). OIs are among the major causes of morbidity and mortality in people living with HIV/AIDS (PLWHA) [1], [2]. These infections are caused by pathogens that are usually harmless in individuals with healthy immune systems but can develop into serious diseases in patients with immune deficiencies such as those with HIV/AIDS. OIs such as Pneumocystis jirovecii pneumonia, oesophageal candidiasis and tuberculosis pose a significant threat to HIV patients who are not receiving adequate antiretroviral therapy (ART) [3]. OIs are classified according to their severity as WHO clinical stages I to IV. More severe infections are thought to be associated with a poor disease prognosis, and their severity depends on the conditions of exposure to the pathogen, the virulence of the pathogen, and the status of the immune system [4]–[6].

The main factor contributing to OIs in PLWHA is a CD4 T-cell count below 200 cells/mm^3 [7]–[9]. A multicenter cohort study in Korea showed that most HIV patients with Pneumocystis jirovecii pneumonia had CD4 T-cell counts below this threshold [10]. In addition to immune suppression, smoking may increase susceptibility to infection by altering inflammatory, vascular, and dendritic-cell responses [11]–[13]. These effects may contribute to infections such as oral candidiasis [14]. Studies among adults living with HIV have reported an association between smoking and oral candidiasis [14], [15], while observational studies have also identified smoking among the behavioral factors examined in relation to broader OI occurrence [16].

Therefore, understanding the relationship between smoking status and the incidence of OIs in PLWHA is essential for more effective management and prevention of infections. This study aimed to determine the association of smoking status with the incidence of OIs in PLWHA based on a systematic review and meta-analysis of reported literature.

Material and Methods

A. Study Design

Studies were identified through several electronic databases, including Google Scholar, PubMed, and ScienceDirect. The literature search was conducted on 25 May 2025. A specific search strategy was developed for each database, including the use of appropriate search fields and filters, such as publication year and language. The following search terms were used: ("Smoking Status" OR "Smoking") AND ("Incidence" OR "Occurrence" OR "Prevalence") AND ("Opportunistic Infections" OR "Opportunistic Diseases") AND ("HIV Patients" OR "HIV-Positive Individuals" OR "People with HIV"). Studies were eligible if they were published in English between 2011 and 2021 and were conducted in various countries. The review process

and reporting were aligned with the PRISMA 2020 statement [17], and the synthesis procedures followed established guidance for systematic reviews and meta-analysis [18], [19].

B. Steps of Meta-Analysis

The meta-analysis was conducted in five steps, starting with formulating the research question in PICO (Population, Intervention, Comparison, Outcome) format, searching for primary study articles from various electronic and non-electronic databases such as Google Scholar, PubMed, and ScienceDirect, screening to determine inclusion and exclusion criteria and conducting critical appraisal, extracting primary study data and synthesizing effect estimates using RevMan version 5.3 application, and interpreting the results and drawing conclusions.

C. Inclusion Criteria

The inclusion criteria were full-text observational studies, including cohort, cross-sectional, case-control, and retrospective studies, that examined the association between smoking status and OIs among PLWHA. Eligible studies reported effect estimates, including odds ratios or adjusted odds ratios, with corresponding 95% confidence intervals (CI).

D. Exclusion Criteria

Studies were excluded if they were published in languages other than English or reported only bivariate effect estimates without multivariable adjustment.

E. Operational Definition of Variables

Article search was carried out by considering the eligibility criteria determined using the PICO model. Population: Patients with HIV. Intervention: Smoking. Comparison: Non-Smoking. Outcome: Opportunistic Infections. Smoking status is defined as a person who currently smokes regularly or has smoked in the past 30 days, be it cigarettes, cigars, pipes, or other forms of tobacco. The measurement scale is categorical. OIs were diagnosed based on clinical, laboratory, and pathology findings, according to the diagnostic criteria reported in the included studies and established guidance for HIV-associated opportunistic infections [20]. OIs such as cervical carcinoma, nontuberculous mycobacteria infection, non-Hodgkin's lymphoma, progressive multifocal leukoencephalopathy, herpes simplex virus infection, Kaposi's sarcoma, cryptococcosis/cryptococcal meningitis, toxoplasmosis/CNS toxoplasmosis, cytomegalovirus (CMV) infection, chronic diarrhea, severe community-acquired pneumonia, recurrent pneumonia/bacterial pneumonia, Pneumocystis jirovecii pneumonia/Pneumocystis carinii pneumonia, herpes zoster, tuberculosis/pulmonary tuberculosis, and oral candidiasis/candidiasis were diagnosed according to the guidelines for diagnosis in the respective countries where the articles were published.

F. Study Instruments

The review was guided by the PRISMA 2020 flow diagram [17]. Methodological quality was assessed using the Critical Appraisal Skills Programme cohort-study checklist [21].

Table 1. Critical Appraisal Checklist using CASP

Author (Year)	Year	Criteria												
		1	2	3	4	5	6	7	8	9	10	11	12	Total
Kim et al. [10]	2016	2	2	2	2	2	2	2	2	2	2	2	2	24
Moges and Kassa [25]	2014	2	2	2	2	2	2	2	2	2	2	2	2	24
Solomon et al. [16]	2018	2	2	2	2	2	2	2	2	2	2	2	2	24
Tewachew et al. [26]	2021	2	2	2	2	2	2	2	2	2	2	2	2	24
Wachamo and Bonja [27]	2020	2	2	2	2	2	2	2	2	2	2	2	2	24
Zerdali et al. [28]	2021	2	2	2	2	2	2	2	2	2	2	2	2	24

The quality of the included studies was assessed using the Critical Appraisal Skills Programme (CASP) checklist [21], with the following items: 1) whether the study addressed a clearly focused research problem; 2) whether the study population was recruited appropriately; 3) whether smoking status was measured accurately to minimize bias; 4) whether opportunistic infections were measured accurately to minimize bias; 5) whether important confounding factors were identified and addressed; 6) whether follow-up was sufficiently complete and long enough, where applicable; 7) whether the results were reported using appropriate measures of association; 8) whether the results were sufficiently precise; 9) whether the results could be trusted; 10) whether the findings could be applied to individuals living with HIV; 11) whether the findings were consistent with other available evidence; and 12) the implications of the findings for clinical and public health practice. Each item was scored as 0 for "No," 1 for "Can't tell," and 2 for "Yes."

G. Data Analysis

The included studies were analyzed using Review Manager version 5.3 [22]. Pooled odds ratios with 95% confidence intervals were calculated, and heterogeneity was evaluated using the I^2 statistic [23]. A fixed-effects model was used for the primary analysis because statistical heterogeneity was low, while a random-effects model was examined as a sensitivity analysis. Forest plots summarized the study-specific and pooled estimates. Funnel-plot interpretation followed recommendations that emphasize caution when fewer than 10 studies are available [24].

Results

The process of searching for articles is carried out through several journal databases which include Google Scholar, PubMed, and ScienceDirect. The review process for related articles can be seen in the PRISMA flow diagram in Fig. 1.

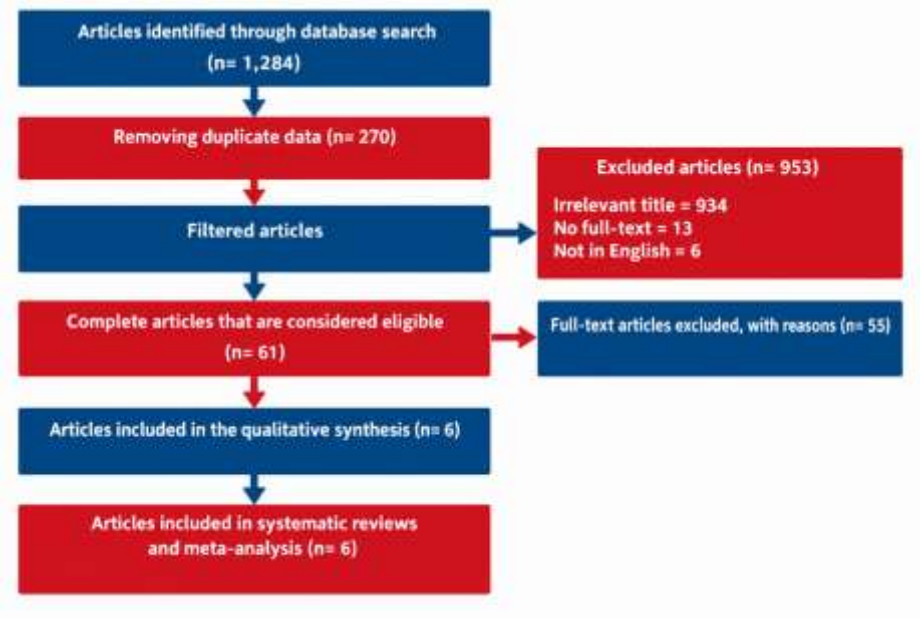

Fig. 1. PRISMA flow diagram of study selection.

This meta-analysis included six observational studies: Kim et al. [10], Moges and Kassa [25], Solomon et al. [16], Tewachew et al. [26], Wachamo and Bonja [27], and Zerdali et al. [28]. The studies used cohort, cross-sectional, case-control, and retrospective designs and were conducted in Korea, Ethiopia, and Turkey. Articles were identified through database searches (n = 1,284), after which 270 duplicates were removed. A total of 953 records were excluded because of irrelevant titles (n = 934), unavailable full texts (n = 13), or non-English publication (n = 6). Of 61 full-text articles assessed for eligibility, six were included in the systematic review and meta-analysis. The primary analysis used a fixed-effects model because statistical heterogeneity was low (I^2 = 0%, p = 0.86), and a random-effects model was applied as a sensitivity analysis. Results were expressed as pooled odds ratios with 95% confidence intervals.

Based on the CASP appraisal [21], the six included studies—Kim et al. [10], Moges and Kassa [25], Solomon et al. [16], Tewachew et al. [26], Wachamo and Bonja [27], and Zerdali et al. [28]—addressed focused research questions and provided data relevant to smoking status and OIs. The appraisal considered participant recruitment, measurement of exposure and outcome, identification of confounding factors, precision, applicability, and consistency with other evidence. Differences in study design, exposure definitions, outcome definitions, and covariate adjustment were nevertheless considered when interpreting the pooled estimate. Overall, the studies were judged sufficiently robust for inclusion, although residual confounding, inconsistent reporting practices, and methodological heterogeneity may have influenced the magnitude and certainty of the observed association estimate.

Table 2. Summary of included studies

Author (Year)	Country	Study Design	Sample IO	Sample Smoking	P	I	C	O	aOR (95% CI)
Kim et al. [10]	Korea	cohort	1086	297	PLWHA	Smoking	No Smoking	OIs	2.27 (1.22–4.26)
Moges and Kassa [25]	Ethiopia	cross-sectional	423	18	PLWHA	Smoking	No Smoking	OIs	1.109 (0.30–4.04)
Solomon et al. [16]	Ethiopia	cross-sectional	744	11	PLWHA	Smoking	No Smoking	OIs	1.85 (1.06–3.24)
Tewachew et al. [26]	Ethiopia	case–control	339	5	PLWHA	Smoking	No Smoking	OIs	1.63 (0.05–5.1)
Wachamo and Bonja [27]	Ethiopia	cross-sectional	414	14	PLWHA	Smoking	No Smoking	OIs	1.03 (0.28–3.83)
Zerdali et al. [28]	Turkey	retrospective	711	414	PLWHA	Smoking	No Smoking	OIs	1.59 (0.79–3.21)

Table 2 shows that the study-specific estimates generally favored higher odds of OIs among smokers. Kim et al. [10] reported an adjusted OR of 2.27 (95% CI 1.22–4.26), and Solomon et al. [16] reported an adjusted OR of 1.85 (95% CI 1.06–3.24). The estimates reported by Moges and Kassa [25], Tewachew et al. [26], Wachamo and Bonja [27], and Zerdali et al. [28] were above 1.0 but did not individually reach statistical significance. These results should be interpreted according to the design, outcome definition, and adjustment strategy used in each primary study.

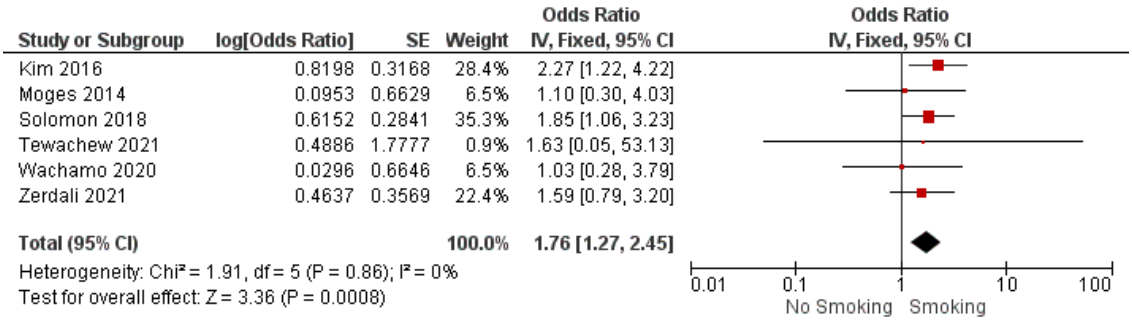

Fig. 2. Forest plot of the relationship between smoking status and the incidence of opportunistic infections in HIV patients

The forest plot (Fig. 2) summarizes the association between smoking status and OIs among PLWHA. Most studies showed effect estimates above 1.0, although only some reached statistical significance. The pooled analysis showed that smoking was associated with higher odds of OIs among PLWHA, with a pooled OR of 1.76 (95% CI: 1.27–2.45). The consistency in effect direction, despite variation in precision, suggests a potentially meaningful association; however, the limited number of studies warrants cautious interpretation and confirmation through larger prospective future studies.

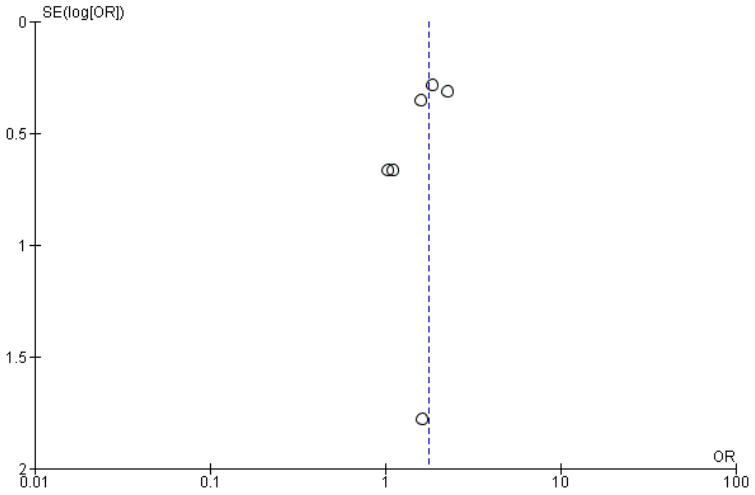

Fig. 3. Funnel plot of the relationship between smoking status and the incidence of opportunistic infections in HIV patients

The funnel plot was used to explore potential small-study effects (Figure 3). Although marked visual asymmetry was not evident, only six studies were included. Because funnel plots have limited power and can be misleading when fewer than 10 studies are available, publication bias could not be reliably assessed [24].

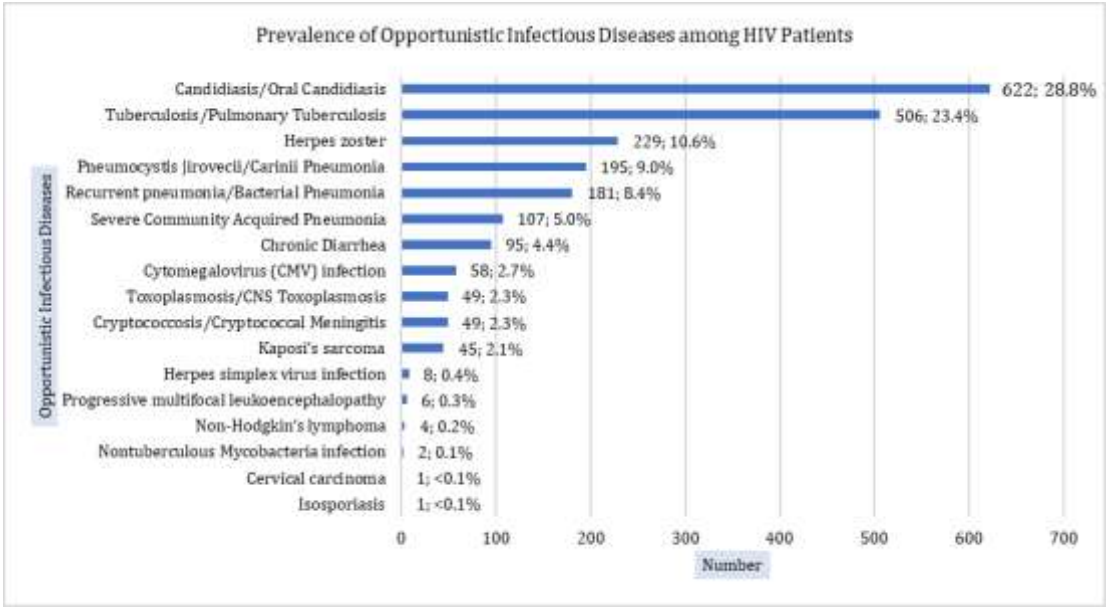

Fig. 4. Prevalence of opportunistic infections among HIV patients

Fig. 4 presents the aggregated distribution of opportunistic infections (OIs) reported across the included studies among people living with HIV. The proportions were calculated based on the total number of reported OI cases (n = 2,160) across the included studies and therefore represent aggregated frequencies rather than pooled prevalence estimates from a prevalence meta-analysis. As individual studies could report more than one type of OI, these

proportions describe the distribution of reported infections and should not be interpreted as the proportion of individual participants affected by each OI.

Candidiasis/oral candidiasis was the most frequently reported OI, accounting for 28.8% (622 cases), followed by tuberculosis/pulmonary tuberculosis was the second most common infection with a prevalence of 23.4% (506 cases), followed by herpes zoster with a prevalence of 10.6% (229 cases). *Pneumocystis jirovecii* pneumonia/*Pneumocystis carinii* pneumonia was recorded at 9.0% (195 cases), and recurrent pneumonia/bacterial pneumonia had a prevalence of 8.4% (181 cases). Other significant infections included severe community-acquired pneumonia at 5.0% (107 cases), chronic diarrhea at 4.4% (95 cases), and Cytomegalovirus (CMV) infection at 2.7% (58 cases). Infections such as toxoplasmosis/CNS toxoplasmosis and cryptococcosis/cryptococcal meningitis each had a prevalence of 2.3% (49 cases). Other types of infections included Kaposi's sarcoma (2.1%), herpes simplex virus infection (0.4%), progressive multifocal leukoencephalopathy (0.3%), non-Hodgkin's lymphoma (0.2%), nontuberculous mycobacteria infection (0.1%), cervical carcinoma (<0.1%), and isosporiasis (<0.1%). Thus, candidiasis/oral candidiasis and tuberculosis/pulmonary tuberculosis were the most frequently reported OIs across the included studies.

Discussion

OIs remain an important cause of illness among PLWHA. The present meta-analysis found that smoking was associated with higher odds of OIs. This finding is biologically plausible because tobacco smoke can disrupt respiratory defenses, alter innate and adaptive immune responses, and increase susceptibility to bacterial, viral, and fungal infections [29]–[31].

The pooled OR was 1.76 (95% CI 1.27–2.45), indicating approximately 76% higher odds of OIs among smokers than among non-smokers. Kim et al. [10] reported the largest statistically significant estimate, whereas Wachamo and Bonja [27] reported an estimate close to the null. The direction of most study-specific estimates was nevertheless consistent with the pooled association. Smoking is also substantially more prevalent among adults receiving HIV care than in the general adult population [32] and contributes materially to mortality among people living with HIV [33].

Variation among study-specific estimates may reflect differences in design, population characteristics, smoking definitions, OI ascertainment, ART exposure, immune status, and covariate adjustment. Although the I^2 value was 0%, this should not be interpreted as proof that the studies were clinically identical. With only six studies, the heterogeneity test has limited power, and uncertainty remains regarding differences across study contexts [23].

The aggregated infection counts showed that candidiasis/oral candidiasis and tuberculosis/pulmonary tuberculosis were the most frequently reported OIs. However, these frequencies should not be interpreted as pooled prevalence estimates because individual studies could report multiple infections and used different populations and diagnostic procedures. The association observed in this review supports the inclusion of smoking assessment and cessation support in routine HIV care. Earlier systematic reviews found that evidence for HIV-tailored smoking-cessation interventions was limited and heterogeneous [34], while an updated Cochrane review emphasized the need for more effective and context-sensitive interventions [35]. WHO similarly recommends integrating tobacco assessment and cessation support into HIV services [36].

Conclusion

Smoking was significantly associated with higher odds of OIs among PLWHA, with the pooled estimate suggesting an approximately 76% increase in odds. Given the substantial burden of infections such as oral candidiasis and pulmonary tuberculosis, integrating structured smoking cessation interventions into routine HIV care should be prioritized. Targeted educational programs and counseling should be implemented to increase awareness of the risks of smoking in the context of immune suppression, strengthen motivation to quit, and support sustained behavior change. When combined with clinical management, these interventions may help reduce OI-related morbidity and improve quality of life among PLWHA.

Conflict of Interest

The authors declare no conflict of interest.

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