**ORIGINAL PAPER**

# Persistent Disparities in Smoking Rates Among PLWH Compared to the General Population in Philadelphia, 2009–2014

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## Abstract

Despite reductions in smoking rates in the general population, little is known about recent smoking trends among people living with HIV (PLWH). We compared the risk for smoking and temporal trends in smoking among PLWH and the general population in the Philadelphia metropolitan area between 2009 and 2014. We used weighted logistic regression to assess the relation between HIV and smoking, and examined temporal smoking trends. The adjusted odds ratio (OR) for smoking comparing PLWH to the general population was 1.80 (95% CI 1.55–2.09) after adjusting for socio-economic, demographic, and mental health diagnosis variables. Smoking prevalence decreased in both the PLWH and general populations during the study period, and we did not observe a significant difference in rates of decline between groups ($P = 0.54$). Despite overall progress in smoking cessation, a disparity persisted in smoking rates between PLWH and the general population, with and without adjustment for socio-economic, demographic, and mental health variables. Further research is needed to understand the mechanisms linking HIV and tobacco use in order to inform public health efforts to reduce smoking among PLWH.

**Keywords** Smoking · Smoking cessation · Tobacco use · HIV infection

## Introduction

Cigarette smoking is the leading preventable cause of death in the United States, resulting in 480,000 deaths annually [1]. In recent years, the prevalence of cigarette smoking has declined significantly in the general US population, from 20.9% in 2005 to 15.5% in 2016 [2]. Multi-level factors have likely contributed to this trend, including implementation of population-based interventions such as smoke-free laws, anti-smoking media campaigns, and increased availability and use of tobacco cessation treatment [3]. However, disparities in tobacco use persist by geographic region, race/ethnicity, and socioeconomic status [4].

Among people living with HIV (PLWH), rates of tobacco use are two to three times higher than the general population in the United States [5]. Estimates of smoking prevalence among PLWH reach 40–70% in some studies [6]. Smoking among PLWH increases the risk for cancer, cardiovascular disease, and respiratory diseases [7, 8]. Furthermore, in settings where anti-retroviral therapy (ART) is readily available, HIV-positive smokers may now lose more life-years to smoking than to HIV infection [9].

Despite overall progress in smoking cessation in the general population, little is known about smoking trends among PLWH. Given elevated baseline rates of smoking among PLWH, the effect of smoking cessation programs may have a more dramatic effect among PLWH, particularly given targeted efforts to reduce smoking among PLWH. On the

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other hand, prior research has indicated that PLWH may have lower quit rates compared to uninfected individuals, but did not compare trends over time [5, 10]. Therefore, it is unknown whether PLWH are making proportionate gains in smoking cessation compared with the general population. In addition, given numerous potential confounding and/or mediating variables between HIV and smoking, it is unclear whether HIV infection may be an independent risk factor for smoking. Therefore, our primary aim was to compare the risk for smoking between PLWH and the general population, while controlling for socio-economic, demographic, and mental health variables that are associated with both smoking and HIV infection. Our secondary aim was to examine and compare temporal trends in smoking between PLWH and the general population in a large US city.

## Methods

We used two health surveillance surveys to investigate cigarette smoking in the general population and among PLWH in the Philadelphia metropolitan area. The PLWH population was represented by annual population-based surveys (2009–2014) from the Philadelphia Medical Monitoring Project (MMP), which sampled persons receiving care from HIV medical facilities. The MMP used a three-stage sampling process with a probability proportion-to-size sampling design, as has been described elsewhere [11]. The general population was represented by the Public Health Management Corporation's Southeastern Pennsylvania Household Health Survey (HHS) in 2008, 2010, 2012, and 2014 [12]. The HHS used a random-digit telephone survey across five counties in the Philadelphia metropolitan area stratified by 54 service areas.

The MMP data included self-reported survey data collected via a standardized survey by trained interviewers, as well as data collected via medical record abstraction. Characteristics included age at survey, sex at birth, race/ethnicity, highest education level, poverty status, health insurance status, incarceration in the past 12 months, housing status, and alcohol and injection drug use. Mental health diagnosis in the MMP was dichotomized as any diagnosis of clinical depression, anxiety disorder, bipolar disorder, psychosis in the medical record, or a score of 10 or greater in the Patient Health Questionnaire-8 administered during the survey, which has been previously validated as a marker of current depression [13]. The HHS data included only self-reported survey data collected via a standardized survey by trained interviewers including age at survey, sex at birth, race/ethnicity, highest education level, poverty level, health insurance status, and mental health diagnosis (defined as any diagnosis of clinical depression, anxiety disorder, bipolar disorder, psychosis).

Both the MMP and HHS data were obtained from complex multi-year survey design where the probability of selection was proportional to the population density within each sampling stratum. In each yearly dataset, every subject was assigned a survey sampling weight to account for project area size and survey nonresponse. For each survey, analyses that pooled data across all years used and assigned each subject an overall sampling weight, calculated as the original weight over the number of years of analysis (six for MMP and four for HHS) [14]. Sampling weights were standardized so that they summed to their respective population sample sizes.

The primary outcome variable for analysis was current smoking status. Current smoking status was determined by participants who reported yes to both of the following questions: (1) "Have you smoked at least 100 cigarettes in your entire life?" (MMP and HHS) and (2) "How often do you smoke cigarettes now?" (MMP: daily, weekly, monthly, less than monthly; HHS: Everyday, Some days). Non-current smokers included former smokers.

We assumed that data collected through MMP and HHS were independent samples with separate design variables and weights. We retained subjects' yearly and overall sampling weights from their original survey. We included individual-level data from both datasets and the following socio-demographic characteristics: age, sex at birth, race/ethnicity, education, poverty level, health insurance status, and mental health diagnosis.

### Data analysis

We conducted univariable and multivariable weighted logistic regression to examine demographic and clinical factors associated with being a current smoker. In our adjusted analyses, we controlled for age, sex, race/ethnicity, education, poverty, insurance, and mental health diagnosis. We used weighted logistic regression to examine linear trends in smoking rates from 2009 to 2014. In order to compare differences in the rate of change of smoking between PLWH and the general population, we used an interaction term between HIV status and year in the model. These models were fit using the SURVEYLOGISTIC procedure in SAS.

For sensitivity analysis, we refit the models using a propensity score matched dataset. This dataset included HIV-positive individuals matched to individuals from the general population using a 1-to-1 propensity score nearest neighbor matching method with the MatchIt package in R (R Core development team, 2019; Vienna, Austria). The propensity score was defined as the conditional probability of being in the HIV-positive cohort given observed covariates. Propensity scores for each subject without missing covariate information were calculated using the covariates age, sex, race/

ethnicity, education, poverty, insurance status, and mental health diagnosis.

Statistical analyses were conducted using R software version 3.6.0 (R Core development team, 2019; Vienna, Austria) and SAS, Version 9.4 (SAS Institute Inc., 2013; Cary, NC) and statistical significance was set at $P = 0.05$ or less.

## Results

A total of 1295 PLWH and 40,079 individuals in the general population were available in the respective surveys. Nine PLWH in the MMP dataset (0.7%) and 223 (0.6%)

in the HHS dataset had missing primary outcome data and were excluded. The remaining 1286 and 39,856 individuals had sampling weights to create our final weighted sample of 9750 in the PLWH population and 3,048,906 in the general population (Table 1). The PLWH population was predominately male (68%), Non-Hispanic Black (62%), at least 40 years of age (75%), and roughly half of PLWH had incomes below the federal poverty level (51%) and had a mental health diagnosis (49%). In comparison, the general population was predominantly female (54%), Non-Hispanic White (67%), had a larger range in age, and most were at or above the federal poverty level (88%) and did not have a mental health diagnosis (83%). Unweighted population

**Table 1** Characteristics of the PLWH and general survey weighted populations with known smoking status over all survey years from the Medical Monitoring Project (MMP) and HHS Household Health Survey (HHS) respectively

| Characteristic | PLWH MMP N = 9750 n (%) | | General HHS N = 3,048,906 n (%) | |
| --- | --- | --- | --- | --- |
| | Nonsmoker N = 5315 (54.5) | Smoker N = 4435 (45.5) | Non-smoker N = 2,468,928 (81.0) | Smoker N = 579,978 (19.0) |
| Age (years) | | | | |
| 18–29 | 647 (12.2) | 411 (9.3) | 397,300 (16.1) | 114,305 (19.7) |
| 30–39 | 759 (14.3) | 644 (14.5) | 368,528 (14.9) | 102,238 (17.6) |
| 40–49 | 1338 (25.2) | 1604 (36.2) | 377,963 (15.3) | 105,542 (18.2) |
| >49 | 2571 (48.4) | 1776 (40.0) | 1,305,864 (52.9) | 255,233 (44.0) |
| Unknown | 0 (0.0) | 0 (0.0) | 19,274 (0.8) | 2660 (0.5) |
| Sex at birth | | | | |
| Male | 3748 (70.5) | 2888 (65.1) | 1,117,690 (45.3) | 290,251 (50.0) |
| Female | 1567 (29.5) | 1532 (34.5) | 1,351,238 (54.7) | 289,727 (50.0) |
| Other/unknown | 0 (0.0) | 15 (0.3) | 0 (0.0) | 0 (0.0) |
| Race/Ethnicity | | | | |
| Non-Hispanic white | 1211 (22.8) | 757 (17.1) | 1,661,701 (67.3) | 350,292 (60.4) |
| Non-Hispanic black | 3127 (58.8) | 2963 (66.8) | 459,642 (18.6) | 155,200 (26.8) |
| Hispanic/Latino | 825 (15.5) | 570 (12.9) | 170,859 (6.9) | 43,014 (7.4) |
| Other/unknown | 152 (2.9) | 145 (3.3) | 176,726 (7.2) | 31,472 (5.4) |
| Education | | | | |
| Less than high school | 1071 (20.1) | 1459 (32.9) | 149,475 (6.1) | 76,739 (13.2) |
| High school/GED | 1749 (32.9) | 1602 (36.1) | 647,008 (26.2) | 243,575 (42.0) |
| More than high school | 2495 (46.9) | 1375 (31.0) | 1,659,360 (67.2) | 257,525 (44.4) |
| Unknown | 0 (0.00) | 0 (0.0) | 13,085 (0.5) | 2139 (0.4) |
| Poverty level | | | | |
| At or above federal | 2944 (55.4) | 1545 (34.8) | 2,231,057 (90.4) | 457,035 (78.8) |
| Below federal | 2150 (40.5) | 2812 (63.4) | 237,206 (9.6) | 122,579 (21.1) |
| Unknown | 221 (4.2) | 78 (1.8) | 666 (0.0) | 364 (0.1) |
| Health insurance status | | | | |
| Not insured | 345 (6.5) | 256 (5.8) | 123,132 (5.0) | 59,080 (10.2) |
| Insured | 4963 (93.4) | 4179 (94.2) | 2,295,129 (93.0) | 494,915 (85.3) |
| Unknown | 7 (0.1) | 0 (0.0) | 50,667 (2.0) | 25,983 (4.5) |
| Mental health diagnosis | | | | |
| No | 3086 (58.1) | 1849 (41.7) | 2,123,661 (86.0) | 408,600 (70.5) |
| Yes | 2229 (41.9) | 2586 (58.3) | 335,694 (13.6) | 168,565 (29.1) |
| Unknown | 0 (0.0) | 0 (0.0) | 9573 (0.4) | 2813 (0.5) |

characteristics are shown in Online Appendix Table 1, and additional characteristics of the PLWH population are shown in Online Appendix Table 2.

Overall, an estimated 45.5% (95% CI 42.6, 48.3) and 19.0% (95% CI 17.6, 20.5) of PLWH and of the general population in the Philadelphia metropolitan area reported current smoking, respectively. Among current smokers, 86.3% (95% CI 83.7, 88.9) of PLWH and 70.4% (95% CI 68.6, 72.1) of the general population reported smoking daily. In unadjusted analyses, PLWH were 3.55 (95% CI 3.06, 4.12) times as likely to report current smoking compared to the general population. In analyses adjusting for age, sex, race/ethnicity, education, poverty, health insurance, and mental health diagnoses, PLWH were 1.80 (95% CI 1.55, 2.09) times more likely to be a current smoker compared with the general population. When we removed mental health diagnoses from the model, PLWH were 2.29 (95% CI 1.98, 2.64) times more likely to be a current smoker compared with the general population. In a sensitivity analysis using propensity-score matched data, we obtained attenuated, but still statistically significant elevated rates of smoking for PLWH compared to the general population with an OR 1.41 (95% CI 1.21, 1.76).

Smoking status declined statistically significantly over time in both groups with the unadjusted OR of smoking per year for PLWH of 0.91 (95% CI 0.85, 0.98) and the general population of 0.96 (95% CI 0.95, 0.98) (Fig. 1). Covariate adjusted ORs were similar and still statistically significant: 0.92 (95% CI 0.86, 0.99) and 0.97 (95% CI 0.95, 0.98), in the PLWH population and general population, respectively. Coefficient estimates and standard errors for each covariate are shown in Online Appendix Table 3. Finally, we compared the change in smoking rates by HIV status. There was no statistically significant difference between the rates of decline in smoking status between PLWH and the general population, as there was no indication of effect modification

in the slope of decline by HIV status in either the unadjusted ($\beta = -0.026$, $P = 0.15$) or adjusted ($\beta = -0.012$, $P = 0.54$) analyses.

## Discussion

We found that rates of current smoking among PLWH were persistently higher than the general population even after controlling for known smoking risk factors. We observed commensurate declines in smoking rates in both PLWH and the general population during the study period. Although the rate of decline over the study period was slightly steeper among PLWH compared to the general population, the observed slopes were not statistically different between the two groups.

This study supports evidence that HIV infection itself may be a risk factor for smoking, and smoking cessation interventions specifically tailored for PLWH may be needed. Prior studies have suggested that higher rates of current smoking among PLWH may be related to socio-demographic factors such as higher rates of poverty, racial/ethnic disparities, and educational disparities mental health diagnoses, and other risk factors associated with HIV infection [10, 15]. However, we found that after controlling for socio-demographic and mental health co-morbidities, PLWH were still more likely to report smoking compared to the general population. Although we were likely unable to account for all unmeasured confounders, this finding is important because it suggests that these socio-demographic factors alone may not explain higher rates of smoking among PLWH. Potential biological mechanisms that explain higher rates of smoking may be faster rates of nicotine metabolism among HIV-positive smokers [16], which has been shown to be associated with severity of nicotine dependence and greater difficulty quitting [17, 18]. For instance, use of the



**Fig. 1** Current smoking prevalence estimates and trend by survey year among PLWH and general population. **a** Shows total population estimates from the unadjusted models, and **b** shows model estimates for a person who is aged 40–49, Male, non-Hispanic black, high school educated, at or above federal poverty, health insured, and has no mental health diagnosis. *MMP* Medical Monitoring Project, representing people living with HIV. *HHS* Household Health Survey, representing the general population
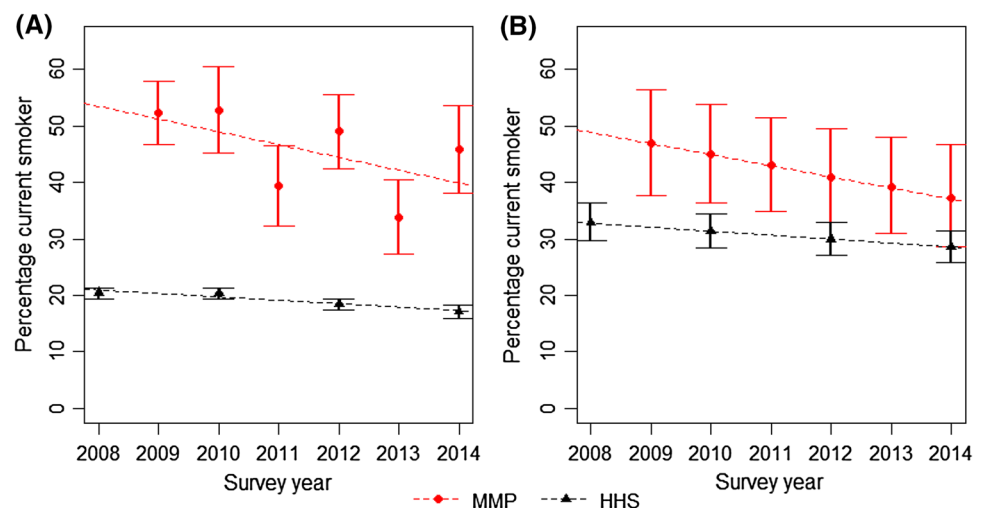
antiretroviral drug efavirenz, has been associated with significantly faster nicotine metabolism among HIV-positive smokers [19]. Prior research has also demonstrated that PLWH may have more difficulty quitting smoking compared to the general population, and the efficacy of smoking cessation pharmacotherapy may be diminished among PLWH [20, 21]. In addition, psychosocial factors [22], internalized HIV stigma [23], and neurocognitive differences [24] associated with HIV may have a significant impact on ongoing tobacco use. Further research is needed to elucidate the mechanisms linking HIV and smoking, which can help inform smoking cessation therapies for PLWH.

The decline in rates of cigarette smoking among PLWH and the general population we observed is similar to previously published literature that examined smoking among PLWH [10]. Rates of smoking in PLWH and the general population in our study were comparable to previously reported national rates [5]. Our study builds upon these prior data by examining differences in the rates of decline between PLWH and the general population. We did not observe a statistically significant difference in the rates of decline, and observed a persistent disparity in smoking rates between PLWH and the general population during all time points. Smoking cessation interventions that focus specifically on HIV-positive smokers are needed to reduce this disparity and accelerate smoking cessation among PLWH. Novel smoking cessation strategies tailored for PLWH include use of mobile technologies and telehealth counseling [25, 26], targeting the neurocognitive complications of HIV [24], treatment of concomitant substance use disorders [27], and tailoring smoking cessation pharmacotherapies and ART regimens for PLWH [19]. Moreover, provider-facing interventions have focused on implementing smoking cessation services across a broad range of clinical settings for PLWH [6, 28].

Several limitations and strengths are worth discussion. Similar to other studies comparing smoking rates in PLWH and the general population, the temporal trend relied on an ecological design. Caution must thus be exercised in making causal inferences based on these findings. Second, our study was limited to a single metropolitan area, thus limiting potential generalizability. However, given observed geographic disparities in smoking rates and variable tobacco-control policies based on region [29], a strength of our study is that it was not subject to potential geographic confounding. Third, PLWH were drawn from the MMP, who may not be representative of all PLWH and may introduce sampling bias with regard to co-morbidities such as tobacco use, mental health diagnoses, and socio-economic status. In addition, PLWH in the MMP were already engaged in HIV care and may not reflect PLWH not on ART. Further research is needed to elucidate the role of ART and viral suppression on smoking cessation among PLWH. Sampling designs were different for the two populations and used different weights.

In order to obtain less biased estimates in our joint analysis, we ensured that the sampling weights were standardized such that they sum to their respective population sample size. In addition, there were differences in data collection on certain variables such as mental health between the two surveys, potentially introducing measurement bias. Despite controlling for multiple potential confounding variables, it is likely that there were still unmeasured confounders, such as substance use and housing status, that could not be controlled for in our analysis due to unavailability in the HHS dataset. Nonetheless, a significant strength of our study was that we controlled for confounding of multiple factors in the multivariable analysis, and conducted a sensitivity analysis with propensity score matching, which generated similar results.

In summary, we observed a persistent disparity in smoking rates between PLWH and the general population. This disparity persisted despite overall progress in smoking rates in both groups and after controlling for multiple concomitant factors. This finding supports evidence that HIV itself may be a risk factor for ongoing tobacco use, and highlights the need for further research that explores potential mechanisms linking HIV and smoking. This research can inform smoking cessation interventions specifically tailored for PLWH, in order to reduce the significant morbidity and mortality burden associated with smoking among PLWH.

## Compliance with Ethical Standards

**Conflict of interest** Dr. Gross serves on a Data and Safety Monitoring Board for Pfizer Inc for medication trials unrelated to HIV or smoking.

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