BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-054903
Article Type:	Original research
Date Submitted by the Author:	30-Jun-2021
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Keywords:	HIV & AIDS < INFECTIOUS DISEASES, Epidemiology < INFECTIOUS DISEASES, Public health < INFECTIOUS DISEASES

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Relationship between Food Insecurity and Smoking among Women Living with and at Risk for HIV in the United States

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Word Count: 3,095 including headers (out of 4,000)
Keywords: Food insecurity, smoking, addiction, HIV, women
Previous presentations: Presented as a poster at the International AIDS Society Conference 2018

Abstract (295 words out of 300)

Objectives: People living with HIV (PLHIV) in the United States (US), particularly women, have a higher prevalence of food insecurity (FI) than the general population. Cigarette smoking among PLHIV is common (42%), and PLHIV are 6-13 times more likely to die from lung cancer than AIDS-related causes. This study sought to investigate the associations between food security status and smoking status and severity among a cohort of predominantly low-income women of color living with and without HIV in the United States.

Design: Women enrolled in an ongoing longitudinal cohort study during 2013-2015.

Setting: Nine participating sites across the United States.

Participants: 2,553 participants enrolled in the Food Insecurity Sub-Study of the Women's Interagency HIV Study, a multisite cohort study of US women living with HIV and demographically similar HIV-seronegative women.

Outcomes: Current cigarette smoking status and intensity were self-reported. We used cross- sectional and longitudinal logistic and Tobit regression to assess associations of food security status and changes in food security status with smoking status and intensity.

Results: The median age was 48. Most respondents were African American/Black (72%) and living with HIV (71%). Over half had annual incomes ≤$12,000 (52%). Food insecurity (44%) and cigarette smoking (42%) were prevalent. In analyses adjusting for common socio-demographic characteristics, all categories of FS were associated with greater odds of current smoking compared to food-secure women. Changes in FS were also associated with increased odds of smoking. Any FI was associated with higher smoking intensity.

Conclusions: FI over time was associated with smoking in this cohort of predominantly low-income women of color living with or at risk of HIV. Integrating alleviation of food insecurity into smoking cessation programs may be an effective method to reduce the smoking prevalence and disproportionate lung cancer mortality rate particularly among PLHIV.

Strengths and Limitations of the Study:

- Although much of the previous literature about smoking among people living with HIV has been conducted among white men, this study was conducted among a large study sample of women, and predominantly women of color.
- The multiple analyses allowed the study to assess multiple relational structures between food security and smoking, including smoking status and smoking intensity.
- The study lacked information on participant use of other tobacco products, notably e-cigarettes, precluding a more comprehensive definition of tobacco use as an outcome.
- There was little variability in smoking status over time.

Background

Cigarette smoking is among the leading causes of excess mortality worldwide[1,2] and the leading risk factor for preventable death in high-income countries such as the United States (US).[3] The prevalence of smoking in the US general adult population was 14% in 2017.[4] The prevalence of smoking among men is 15.8% compared to 12.2% of women.[5] The prevalence of cigarette smoking is also substantially higher among low-income individuals at and below the federal poverty level, with 41% of low-income men and 32% of low-income women who smoke and higher proportions using all other forms of tobacco, including cigarettes.[6] Women in general have a harder time quitting smoking,[7] both "cold-turkey"[8] and through other methods such as the patch,[9] compared to men, leading to longer lifetime smoking duration and nicotine exposure compared to men.

The prevalence of smoking among people living with HIV (PLHIV) is 42%, similar to that among the low-income general population and more than double the general population estimates.[10] Beyond the well-documented sequelae of cigarette smoking in the general population,[3] PLHIV who are smokers additionally experience a higher risk of pneumonia,[11] emphysema,[12] and other illnesses of the lung,[13] compared to their HIV seronegative counterparts who smoke. Further, PLHIV who smoke also have higher odds of a detectable viral load[14,15] and faster progression to AIDS compared to non-smoking PLHIV.[16] PLHIV who smoke are also 6 to 13 times more likely to die from lung cancer than from AIDS-related causes.[17]

Despite sex differences in cigarette smoking prevalence in the general US population,[4] cigarette smoking prevalence does not differ by sex among PLHIV. Smoking among women living with HIV (WLWH) may have additional reproductive and maternal health consequences, including a higher risk of pre-eclampsia than both HIV seronegative- and non-smoking WLWH counterparts,[18] increased fetal morbidity compared to HIV seronegative smokers,[19] and earlier onset of natural menopause compared to non-smoking WLWH.[20] On the whole, these smoking-specific health consequences may have additive or multiplicative interactions with general HIV-related conditions,[21] thereby reducing the immunological support of antiretroviral therapy.[22]

Food insecurity, defined as "the uncertain or limited availability of nutritionally adequate or safe food or the inability to procure food in socially acceptable ways,"[23,24] is prevalent in low-income households and has been linked to smoking in the general population.[25,26] Food insecurity affects 12% of American households and 16% of households with a child under eighteen.[27] Food insecurity is more prevalent among

households led by women and women living alone, ethnic and racial minorities, and households with children (compared to the general US prevalence).[27]

Estimates of food insecurity among PLHIV range from 20-50%,[28,29] with higher prevalence among WLWH compared to their male counterparts.[30,31] Food insecurity among PLHIV is associated with decreased mental and physical health status,[32] suboptimal adherence to antiretroviral therapy,[33] use of illicit substances,[34] and increased HIV-related morbidity and HIV mortality.[35] Important limitations in the studies investigating smoking among PLHIV include that they were conducted among predominately male populations living with HIV,[36-38] lacked granularity in the smoking variable,[36,38] or did not examine smoking severity.[37,38] Given that tobacco use is the most important preventable cause of excess mortality worldwide, with increased health consequences to PLHIV and WLWH specifically, expanding our understanding of the role of food insecurity as a potentially modifiable factor among WLWH is vital to reducing these health disparities. Therefore, we conducted an analysis of data from the Women's Interagency HIV Study (WIHS) to understand the associations between food insecurity and smoking over time. We hypothesized that: 1) greater severity of current food insecurity would be associated with higher odds of being a current smoker, 2) food security status over time would be associated with smoking status, and 3) greater severity of current food insecurity would be associated with higher intensity of smoking.

Methods

Data

Data for this study originated from the WIHS, a longitudinal cohort study of WLWH and demographically similar HIV seronegative controls in the United States (US) that began in 1993, with two additional waves of enrollment in 2001-2002 and 2011-2012. In 2013-2014, four new sites in the Southern US were added to enroll women representative of the updated demographic profiles of WLWH in the US.[39,40] For the duration of this study, the WIHS collected socio-behavioral, biological, and clinical data from all participants during semi-annual visits using interviewer-administrated standardized instruments, physical exams, and standard phlebotomy. The physical examination includes standard anthropometry, weight, and a gynecologic examination. Immunologic and virologic biomarker measurements included current CD4 count and HIV RNA viral load.

Beginning in 2013, the Food Insecurity Sub-Study added data on comprehensive measures of food security, dietary intake, household savings, and food support among WIHS women at nine sites: Bronx, NY; Brooklyn, NY; Washington, D.C.; Chicago, IL; San Francisco, CA; Chapel Hill, NC; Miami, FL;

Birmingham, AL/Jackson, MS; and Atlanta, GA. The analyses in this paper used data on 11,692 person-visits from 2,553 women total (1,803 living with and 750 without HIV collected from April 2013 to March 2016 at every semi-annual visit. Participants provided written informed consent and were compensated for participation. This study was approved by the Institutional Review Board at each study site's institution and by the WIHS Executive Committee.

Measures

Exposure: The exposure was food insecurity, measured using the US Department of Agriculture's Household Food Security Module (HFSSM).[41] The HFSSM has been validated in high-resource settings among both vulnerable populations[42,43] and those living with HIV, and is the reference measure of food security in the US.[44] The HFSSM includes 18 items about insufficient food quantity, low diet quality, uncertainty about food, and food affordability.[42] The HFSSM uses recall periods of twelve months and 30 days; the WIHS module was worded to ask about food security over the previous six months or since the last WIHS visit. The HFSSM scoring algorithm categorizes individuals as having high, marginal, low, or very low food security.[44] Cronbach's alpha for the HFSSM in this sample was 0.91, indicating high internal consistency.

Primary outcomes: The primary outcomes were 1) current cigarette smoking status (smoker vs. non-smoker) and 2) smoking intensity (number of cigarettes/day). Both outcomes were assessed by self-report at each visit during the interviewer-administered interview. Participants were asked "Since your study visit on [previous study visit date], have you smoked cigarettes?" Among those who responded yes, they were further prompted to recall how many cigarettes on average they smoked per day. Given the non-normal distribution of cigarettes smoked per day, the values above zero for this variable were transformed by the natural logarithm. Those who reported zero cigarettes per day were not transformed and were retained as being left-censored. Per WIHS protocol, all participants who reported current smoking were subsequently referred to a smoking cessation program.

Covariates: Covariates were selected *a priori* based upon review of the literature regarding food security and smoking. Covariates included HIV status (seropositive or seronegative [reference group]), age at visit (per year at visit), race/ethnicity (non-Hispanic white [reference group], non-Hispanic African-American/Black, Hispanic, and non-Hispanic other), annual household income as collected by WIHS (≤$12,000 [reference group], $12,001-$24,000, $24,001-$36,000, $36,001-$75,000 and ≥$75,001), employment status (employed [reference group] or unemployed), marital status (partnered [reference

group], divorced/widowed/separated, never married, or other), educational attainment (less than high school education [reference group] or greater than a high school education or equivalent), and if they had child dependents < age 18 in the household (none [reference group] or yes). Response options were in reference to the previous six months. Given that food insecurity is associated with several mental health outcomes including depression,[32] anxiety and stress,[45] and illicit substance use,[46] and there is likely a bidirectional association between smoking and mental health,[47,48] mental health may be a mediator rather than a confounder on the path from food insecurity to smoking outcomes. Therefore, we did not adjust for mental health variables, as these could potentially be on the causal path from food insecurity to smoking outcomes.

Analysis

Summary statistics were obtained for food insecurity, the smoking outcomes, and all covariates at study baseline (i.e., the first visit during the Food Insecurity Sub-Study). We used a logistic regression model with one cross-sectional sample at the first measure of food insecurity (food insecurity sub-study baseline) to assess the association between food security status and the odds of being a current smoker (hypothesis 1). We also modelled an interaction term between food security and HIV status to assess whether food security in the presence of HIV-seropositivity was associated with differential odds of smoking compared to food secure, HIV-seronegative women. Next, we used a longitudinal logistic regression model with fixed effects for individuals to assess the association between food security status and the odds of being a current smoker (hypothesis 2). This model did not include time-invariant covariates to rule out potential confounding by unobserved time-invariant characteristics. The fixed-effects model removed all individuals who did not have a change in smoking status over the study visits, allowing us to examine just those who had a change in smoking status and leaving a sample of 344 women (comprising 1,700 person-visits). Given that this model removes person-to-person variability, it allows for the interpretation of change as effects are generated only by those who experience any change. The coefficients from this model are interpreted as adjusted odds ratios. Finally, we used longitudinal Tobit regression to model the association between food security and smoking intensity (natural logarithm of cigarettes/day) (hypothesis 3). Tobit models allow for censoring and were thus implemented given that a large proportion of the values for cigarettes per day were left-censored as over half of women in the sample were non-smokers. Given that cigarettes per day was transformed to the logarithmic scale, the results from the Tobit model are presented as exponentiated coefficients and interpreted as a relative difference (i.e., multiplicative factor) compared to the reference category. All analyses were conducted using Stata 14 (College Station, TX:

StataCorp LP).

Patient and public involvement

There was no patient or public involvement in the development of the research questions or in the analyses.

Results

At the Food Insecurity Sub-Study baseline, 42% of women reported being current smokers and 44% reported any category of food insecurity (Table 1). Among current smokers, the median number of cigarettes smoked per day was five (interquartile range (IQR): 3, 10). The median age of women was 48 years (IQR: 40, 54) and women were predominantly HIV-seropositive (71%), and of African American/Black race (72%), followed by Hispanic women (15%). Nearly two thirds of the women reported an education equivalent to or greater than high school (67.4%) and were unemployed at baseline (65%). Over half had annual household incomes less than $12,000.

In the first adjusted model among 2,133 women, current marginal, low, and very low food security was associated with 1.52 (95% confidence interval (CI) 1.14, 2.04), 1.70 (95% CI 1.28, 2.27), and 1.91 (95% CI 1.42, 2.59) times greater odds of being a current smoker compared to those with high food security (all $p<0.01$) (Table 2). HIV-seropositivity was associated with lower odds of being a current smoker (adjusted odds ratio (AOR): 0.66; 95% CI 0.53, 0.81, $p<0.001$). The association between food security status and current smoking was not modified by HIV status (not shown).

In the longitudinal individual fixed-effects model, becoming marginal, low and very low food security were associated with 1.56 (95% CI: 1.08, 2.25), 1.88 (95% CI: 1.23, 2.87), and 1.66 (95% CI: 1.02, 2.81) times greater odds of becoming a current smoker, respectively. In this model, none of the other time-varying variables were significantly associated with becoming a current smoker.

In the final model for smoking intensity, all study participants were included with nonsmokers censored at zero. The adjusted odds of intensity of smoking (cigarettes/day) were 1.17 (95% CI: 1.07, 1.27), 1.21 (95% CI: 1.10, 1.32), and 1.16 (95% CI: 1.04, 1.29) times higher for women with marginal, low, and very low food security status, respectively, compared to those with high food security.

Discussion

In this longitudinal study of women living with HIV and demographically similar women without HIV, food insecurity was associated with greater odds of being a current cigarette smoker, with higher odds of smoking as food insecurity severity worsened. Furthermore, any change in food security status were associated with a change in smoking status, and food insecurity was associated with smoking intensity. HIV status did not modify these associations, but HIV-seropositivity was associated with lower odds of being a current smoker and lower intensity of smoking compared to HIV-seronegative participants.

Our findings are consistent with literature on food insecurity and smoking among the general US population but not among WLWH.[26] In WIHS, all women who reported smoking received information at each visit referring them to external smoking cessation programs, which may partially explain the low prevalence in the sample. Similarly, due to the nature of healthcare in the United States, women living with HIV may have access to more consistent healthcare compared to their demographically similar HIV-seronegative counterparts, allowing for more opportunities for smoking cessation referrals, which may in part explain the lower prevalence of smoking among WLWH in this study. Nevertheless, our study was predominantly comprised of an understudied sub-population among PLHIV, given that economically disadvantaged people and ethnic minorities typically have less access to smoking cessation treatment and[49,50] women in general have less success in smoking cessation in the long term than men.[7]

Being food insecure was associated with 1.16-1.21 times higher (i.e., 16-21% higher) smoking intensity compared to being food secure, even after controlling for income. The association of income with smoking intensity was essentially the same across all income levels. Several plausible mechanisms may explain this finding. Being food insecure may reflect volatility in financial resources, which in turn may affect one's ability to afford highly taxed cigarettes and subsequent smoking intensity. People of low socioeconomic status are more likely to respond to increased cigarette taxation in the form of reduced consumption than those of higher socioeconomic status.[51,52] At the same time, if food-insecure people have access to programs that alleviate but not eliminate food insecurity (allowing them to go from a previously very low food security status to low or moderate) via food banks/pantries or food stamps, then resources previously dedicated to food may be available for non-essential goods including cigarettes. Conversely, a consequence of alleviation of food insecurity is a reduction in smoking intensity because smoking acts as an appetite suppressant via the hypothalamus,[53,54] and food insecure individuals may

smoke to cope with hunger.[55,56] Our results corroborate this potential mechanism as the cross-sectional model demonstrates that as food insecurity worsens, the odds of being a smoker increase. Becoming food insecure compared to maintaining a food insecure status is associated with lower odds of smoking cessation among smokers.[26] But there is no evidence demonstrating the reverse, in that a change from being food-insecure to becoming food secure may prompt a reduction or cessation in cigarette smoking, presumably as the appetite-suppressing effects of cigarettes are no longer needed. This study was unable to assess food insecurity nor changes in food security status as a predictor of smoking cessation success.

The study included a large, geographically diverse sample of women living with HIV and demographically similar controls. A rich set of information was collected for each woman and models adjusted for appropriate control variables. Nevertheless, several potentially important individual characteristics that were not measured were smoking products and smoking behaviors, family history of smoking, previous cessation attempts, social support, and participation in food insecurity alleviation programs. Given that there were few differences in the longitudinal model (compared to the cross-sectional model) when we were able to control for individual variability, as well as the fixed effects model (which removed measured and unmeasured individual characteristics that do not change over time), the role of these potential confounders may be minimal. Collecting data on smoking intensity is notoriously difficult given variabilities in recalling smoking intensity. The survey questions assessed smoking intensity since the last visit six months earlier; long recall periods present opportunities for recall bias in self-reporting of health data. Likewise, food insecurity was assessed during that same recall period. Food security status may fluctuate on a monthly or weekly basis in households experiencing food or financial scarcity; a recall period of six months may not allow us to evaluate these periodic shifts. Further, we were unable to assess other types of common tobacco use, notably vaping and e-cigarettes, whose prevalence and public health impact are increasing greatly. The development of validated questions that can evaluate tobacco exposure from traditional (i.e., cigarette, chewing tobacco, cigars) as well as new delivery mechanisms (i.e. e-cigarettes, vaping) will facilitate a more accurate measurement of tobacco exposure. This potential misclassification in the exposure could result in biasing the results towards the null, whereby women who are food insecure and exclusive vape users were categorized as non-smokers, yet the paths from food insecurity and tobacco use and addiction potentially remain the same. Furthermore, although the prevalence of self-reported cigarette smoking was not low in the sample, there was little change in status over the assessed study visits. Lastly, despite recent recruitment efforts to match the demographic profile of women living with HIV in the US,[40] WIHS women may not match the profile of those with

incident HIV in the US, notably in regards to age, which has implications for the generalizability of this study.

In conclusion, food insecurity was associated with both smoking and smoking intensity in this sample of women living with HIV and HIV-seronegative women. Smoking has a high attributable risk for preventable deaths in the US and globally, and food insecurity exacerbates this risk. Food insecurity is modifiable and alleviating it should be considered as part of or in conjunction with smoking cessation programs. Experimental or observational studies of programs to alleviate food insecurity should collect data on recent tobacco initiators or quitters to provide valuable information on the contextual milieu that is related to smoking initiation, duration, intensity, and cessation. With such information, researchers may be able to better identify those at risk for tobacco use initiation as well as enhance smoking cessation.

Contributorship statement:
Planning: SDW, PT, EF; Research and study design: LAS, SDW, EF, PT; data analysis: LAS, EF; data interpretation: LAS, SDW, EF, JH, ER; data collection: LAS, KP, TW, AA, DM, MC, EW, AA, IO, EW, LM, JMT, PT, SDW; All authors reviewed and provided feedback on intellectual content and approved the final version of the manuscript.

Competing Interests:
There are no competing interests for any author.

Funding
This study was funded by a Women's Interagency HIV Study (WIHS) sub-study grant from the National Institute of Mental Health, R01MH095683, a mentoring grant K24AI134326 (Weiser), and a scientist development grant K01DK107335 (Palar). Data in this manuscript were collected by the Womens Interagency HIV Study (WIHS), now the MACS/WIHS Combined Cohort Study (MWCCS). The contents of this publication are solely the responsibility of the authors and do not represent the official views of the National Institutes of Health (NIH). MWCCS (Principal Investigators): Atlanta CRS (Ighovwerha Ofotokun, Anandi Sheth, and Gina Wingood), U01-HL146241; Baltimore CRS (Todd Brown and Joseph Margolick), U01-HL146201; Bronx CRS (Kathryn Anastos and Anjali Sharma), U01-HL146204; Brooklyn CRS (Deborah Gustafson and Tracey Wilson), U01-HL146202; Data Analysis and Coordination Center (Gypsyamber D'Souza, Stephen Gange and Elizabeth Golub), U01-HL146193; Chicago-Cook County CRS (Mardge Cohen and Audrey French), U01-HL146245; Chicago-Northwestern CRS (Steven Wolinsky), U01-HL146240; Northern California CRS (Bradley Aouizerat, Jennifer Price, and Phyllis Tien), U01-HL146242; Los Angeles CRS (Roger Detels and Matthew Mimiaga), U01-HL146333; Metropolitan Washington CRS (Seble Kassaye and Daniel Merenstein), U01-HL146205; Miami CRS (Maria Alcaide, Margaret Fischl, and Deborah Jones), U01-HL146203; Pittsburgh CRS (Jeremy Martinson and Charles Rinaldo), U01-HL146208; UAB-MS CRS (Mirjam-Colette Kempf, Jodie Dionne-Odom, and Deborah Konkle-Parker), U01-HL146192; UNC CRS (Adaora Adimora), U01-HL146194. The MWCCS is funded primarily by the National Heart, Lung, and Blood Institute (NHLBI), with additional co-funding from the Eunice Kennedy Shriver National Institute Of Child Health & Human Development (NICHD), National Institute On Aging (NIA), National Institute Of Dental & Craniofacial Research (NIDCR), National Institute Of Allergy And Infectious Diseases (NIAID), National Institute Of Neurological Disorders And Stroke (NINDS), National Institute Of Mental Health (NIMH), National Institute On Drug Abuse (NIDA), National Institute Of Nursing Research (NINR), National Cancer Institute (NCI), National Institute on Alcohol Abuse and Alcoholism (NIAAA), National Institute on Deafness and Other Communication Disorders (NIDCD), National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), National Institute on Minority Health and Health Disparities (NIMHD), and in coordination and alignment with the research priorities of the National Institutes of Health, Office of AIDS Research (OAR). MWCCS data collection is also supported by UL1-TR000004 (UCSF CTSA), P30-AI-050409 (Atlanta CFAR), P30-AI-050410 (UNC CFAR), and P30-AI-027767 (UAB CFAR).

Data Sharing:
You may request access to the MACS or WIHS Public Use Data Set (MWCCS public use data set will be available in 2021 at https://airtable.com/shrVDP51W5J2qcNeT), or you may submit a concept sheet in order to have access to the full MWCCS data set, which includes data not available in the PDS such as neurocognitive

data, abuse data, healthy aging, etc. Having an approved concept sheet means you will receive assistance in understanding the MWCCS study and the complexity of the MWCCS data; linkage to a MWCCS liaison who can offer expertise in your area of study; support regarding study design, methodology, and statistical analysis; and access to all summary files.

Ethics Statement:
Institutional Review Boards at each of the following universities or institutions reviewed and approved the study procedures (per the MWCCS overall study director, approval numbers are not available):

- University of Mississippi Medical Center
- University of North Carolina at Chapel Hill
- University of Alabama at Birmingham
- University of Miami
- Emory University

Brooklyn WIHS site
- SUNY Downstate Medical Center
- Kings County Medical Center

Bronx WIHS site
- Montefiore Medical Center
- Beth Israel Medical Center
- Mount Sinai School of Medicine

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- Santa Clara Valley Medical Center
- San Mateo Medical Center

DC WIHS site
- Georgetown University
- Montgomery County Department of Health and Human Services
- Inova
- Howard University
- Whitman-Walker Clinic

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Table 1: Sociodemographic characteristics of the sample at first visit in the Food Insecurity Sub-Study, Women's Interagency HIV Study (n=2,553 unique women)

	All women	HIV Seropositive N=1803	HIV Seronegative N=750
	N (%) or median (inter-quartile range [IQR])		
Current food security (FS)			
High	1,419 (55.6)	1006 (55.8%)	413 (55.1%)
Marginal FS	405 (15.9)	287 (15.9%)	118 (15.7%)
Low FS	372 (14.6)	263 (14.6%)	109 (14.5%)
Very low FS	357 (14.0)	247 (13.7%)	110 (14.7%)
Current Smoker	1075 (42.1)	706 (39.2%)	369 (49.2%)
Age at visit, yr (median, IQR)	47.7 (40.4, 53.8)	48.2 (41.3, 54.0)	46.1 (38.1, 53.0)
Race			
Non-Hispanic white	255 (10.0)	196 (10.9%)	59 (7.9%)
Hispanic	377 (14.8)	262 (14.5%)	115 (15.3%)
Non-Hispanic African American/Black	1,829 (71.6)	1290 (71.5%)	539 (71.9%)
Non-Hispanic Other	92 (3.6)	55 (3.1%)	37 (4.9%)
Annual Household Income			
<$12000	1,261 (51.9)	925 (53.7%)	337 (47.5%)
$12001-24,000	541 (22.3)	381 (22.1%)	160 (22.5%)
$24,001-$36,000	267 (11.0)	180 (10.5%)	87 (12.3%)
$36,001-75,000	249 (10.2)	153 (8.9%)	96 (13.5%)
$75001	113 (4.7)	83 (4.8%)	30 (4.2%)
Employed (ref: unemployed)	891 (35.0)	592 (32.9%)	299 (40.0%)
Marital status			
Partnered	762 (30.8)	531 (30.4%)	231 (32.0%)
Divorced/separated/Widowed	660 (26.7)	476 (27.2%)	184 (25.4%)
Never Married	800 (32.4)	577 (33.0%)	223 (30.8%)
Other	250 (10.1)	165 (9.4%)	85 (11.8%)
Education (ref: <high school)			
≥High school education	1719 (67.4)	1204 (66.8%)	515 (68.8%)
Child dependents (ref: No)			
Yes	986 (38.6)	664 (36.8%)	322 (42.9%)

Table 2: Adjusted associations between food security and smoking outcomes

VARIABLES	Cross sectional association between food security status and current smoking AOR (95% CI)	Longitudinal fixed-effect model examining changes in food security and current smoking AOR (95% CI)	Longitudinal Tobit model examining food security status and smoking intensity Relative difference (95% CI)
Current food security (FS)			
High	Ref.	Ref.	Ref.
Marginal FS	1.52** (1.14 - 2.04)	1.56* (1.08 - 2.25)	1.17*** (1.07 - 1.27)
Low FS	1.70*** (1.28 - 2.27)	1.88** (1.23 - 2.87)	1.21*** (1.10 - 1.32)
Very low FS	1.91*** (1.42 - 2.59)	1.66* (1.02 - 2.71)	1.16** (1.04 - 1.29)
HIV seropositivity (neg ref.)	0.59*** (0.48 - 0.73)	--	0.57*** (0.46 - 0.71)
Age at visit, years	0.99 (0.98 - 1.00)	0.95 (0.83 - 1.08)	1.01 (1.00 - 1.02)
Race			
Non-Hispanic White	Ref.	--	Ref.
Hispanic	0.59* (0.39 - 0.90)	--	0.54** (0.36 - 0.80)
African American/ Black	1.02 (0.73 - 1.44)	--	0.99 (0.71 - 1.38)
Other	0.77 (0.42 - 1.40)	--	0.60 (0.33 - 1.07)
Income			
<$12000	Ref	Ref	Ref
$12001-24,000	0.78* (0.61 - 0.98)	1.05 (0.73 - 1.52)	0.89** (0.81 - 0.97)
$24,001-$36,000	0.84 (0.60 - 1.17)	1.05 (0.61 - 1.82)	0.82** (0.72 - 0.93)
$36,001-75,000	0.62* (0.42 - 0.93)	2.38* (1.05 - 5.39)	0.80** (0.69 - 0.94)
$75001	0.37** (0.19 - 0.71)	1.94 (0.48 - 7.80)	0.54*** (0.42 - 0.71)
Employed (unemployed ref.)	0.45*** (0.36 - 0.57)	1.47 (0.94 - 2.30)	0.89** (0.81 - 0.97)
Marital status			
Partnered	Ref	Ref	Ref
Divorced/separated/Widowed	0.91 (0.70 - 1.17)	0.68 (0.40 - 1.14)	0.92 (0.82 - 1.03)
Never Married	0.94 (0.74 - 1.19)	0.98 (0.57 - 1.69)	1.00 (0.89 - 1.13)
Other	1.07 (0.76 - 1.51)	0.68 (0.36 - 1.27)	0.92 (0.79 - 1.06)
Education (<high school ref)			
≥High school education	0.54*** (0.44 – 0.66)	--	0.42*** (0.34 - 0.52)
Child dependents (no ref)			
Yes	0.66*** (0.48, 0.73)	0.85 (0.56 - 1.29)	0.91 (0.83 - 1.00)
Observations	2,133	1,700	11,301
Number of WIHSID	2,133	344	2,522

*** p<0.001, ** p<0.01, * p<0.05

BMJ Open

Relationship between Food Insecurity and Smoking Status among Women Living with and at Risk for HIV in the USA: A Cohort Study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-054903.R1
Article Type:	Original research
Date Submitted by the Author:	09-Aug-2021
Complete List of Authors:	Sheira, Lila; University of California San Francisco, Division of HIV, Infectious Diseases, and Global Medicine Frongillo, EA; University of South Carolina System, Department of Health Promotion, Education, and Behavior Hahn, Judith; University of California San Francisco, Division of HIV, Infectious Diseases, and Global Medicine Palar, Kartika; University of California San Francisco, Division of HIV, Infectious Diseases, and Global Medicine Riley, Elise; University of California San Francisco, Division of HIV, Infectious Diseases, and Global Medicine Wilson, Tracey; State University of New York Downstate Medical Center, Community Health Sciences, School of Public Health Adedimeji, Adebola; Albert Einstein College of Medicine, Dept. of Epidemiology and Population Health Merenstein, Daniel; Georgetown University Medical Center, Family Medicine Cohen, Mardge; John H Stroger Hospital of Cook County, Medicine Wentz, Eryka; Johns Hopkins University, Department of Epidemiology Adimora, Adaora; University of North Carolina at Chapel Hill Gillings School of Global Public Health, School of Medicine; University of North Carolina at Chapel Hill School of Medicine, Gillings School of Public Health Ofotokun, Ighovwerha; Emory University, School of Medicine Metsch, Lisa; Columbia University Mailman School of Public Health, Sociomedical Sciences Turan, Janet M.; The University of Alabama at Birmingham School of Public Health, Sociomedical Sciences Tien, Phyllis ; University of California San Francisco, Medicine; Veteran Affairs Medical Center Weiser, Sheri; University of California San Francisco, Division of HIV, ID and Global Medicine; University of California San Francisco, Center for AIDS Prevention Studies
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	HIV/AIDS, Public health, Smoking and tobacco
Keywords:	HIV & AIDS < INFECTIOUS DISEASES, Epidemiology < INFECTIOUS DISEASES, Public health < INFECTIOUS DISEASES

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Relationship between Food Insecurity and Smoking Status among Women Living with and at Risk for HIV in the USA: A Cohort Study

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Word Count: 3,890 including headers and strengths and limitations (out of 4,000)
Keywords: Food insecurity, smoking, addiction, HIV, women
Previous presentations: Presented as a poster at the International AIDS Society Conference 2018

Abstract (297 words out of 300)

Objectives: People living with HIV (PLHIV) in the United States (US), particularly women, have a higher prevalence of food insecurity than the general population. Cigarette smoking among PLHIV is common (42%), and PLHIV are 6-13 times more likely to die from lung cancer than AIDS-related causes. This study sought to investigate the associations between food security status and smoking status and severity among a cohort of predominantly low-income women of color living with and without HIV in the United States.

Design: Women enrolled in an ongoing longitudinal cohort study from 2013-2015.

Setting: Nine participating sites across the United States.

Participants: 2,553 participants enrolled in the Food Insecurity Sub-Study of the Women's Interagency HIV Study, a multisite cohort study of US women living with HIV and demographically similar HIV- seronegative women.

Outcomes: Current cigarette smoking status and intensity were self-reported. We used cross-sectional and longitudinal logistic and Tobit regression to assess associations of food security status and changes in food security status with smoking status and intensity.

Results: The median age was 48. Most respondents were African American/Black (72%) and living with HIV (71%). Over half had annual incomes ≤$12,000 (52%). Food insecurity (44%) and cigarette smoking (42%) were prevalent. In analyses adjusting for common socio-demographic characteristics, all categories of food insecurity were associated with greater odds of current smoking compared to food-secure women. Changes in food insecurity were also associated with increased odds of smoking. Any food insecurity was associated with higher smoking intensity.

Conclusions: Food insecurity over time was associated with smoking in this cohort of predominantly low-income women of color living with or at risk of HIV. Integrating alleviation of food insecurity into smoking cessation programs may be an effective method to reduce the smoking prevalence and disproportionate lung cancer mortality rate particularly among PLHIV.

Strengths and Limitations of the Study:

- Although much of the previous literature about smoking among people living with HIV has been conducted among white men, this study was conducted among a large study sample of women, and predominantly women of color.
- The analyses allowed the study to estimate multiple relational structures between food insecurity and smoking, including smoking status and smoking intensity.
- The study lacked information on participant use of other tobacco products, notably e-cigarettes, precluding a more comprehensive definition of tobacco use as an outcome.
- Smoking status varied little over time, which may have limited estimation of the relationship between changes in smoking status and infood security.

Background

Cigarette smoking is among the leading causes of excess mortality worldwide[1,2] and the leading risk factor for preventable death in high-income countries such as the United States (US).[3] The prevalence of smoking in the US general adult population was 14% in 2017.[4] In 2019, the prevalence of smoking among men was 15.3% compared to 12.7% of women.[5] The prevalence of cigarette smoking is also substantially higher among low-income individuals at and below the federal poverty level, among whom 41% of men and 33% of women smoke[6] and higher proportions use all other forms of tobacco, including e-cigarettes.[7] Women in general have a harder time quitting smoking,[8] both "cold-turkey"[9] and through other methods such as the patch,[10] compared to men, leading to longer lifetime smoking duration and nicotine exposure.

The prevalence of smoking among people living with HIV (PLHIV) is 42%, similar to that among the low-income general population and more than double the general population estimates.[11] Beyond the well-documented sequelae of cigarette smoking in the general population,[3] PLHIV who are smokers additionally experience a higher risk of pneumonia,[12] emphysema,[13] and other illnesses of the lung,[14] compared to their HIV seronegative counterparts who smoke. Further, PLHIV who smoke also have higher odds of a detectable viral load[15,16] and faster progression to AIDS compared to non-smoking PLHIV.[17] Nearly one-quarter of deaths among PLHIV can be attributed to current smoking,[18] and PLHIV who smoke are also 6 to 13 times more likely to die from lung cancer than from AIDS- related causes.[19]

Despite sex differences in cigarette smoking prevalence in the general US population, [4] cigarette smoking prevalence does not differ by sex among PLHIV. Smoking among women living with HIV (WLWH) may have additional reproductive and maternal health consequences, including a higher risk of pre-eclampsia than both HIV seronegative- and non-smoking WLWH counterparts,[20] increased fetal morbidity compared to HIV seronegative smokers,[21] and earlier onset of natural menopause compared to non-smoking WLWH.[22] On the whole, these smoking-specific health consequences may have additive or multiplicative interactions with general HIV-related conditions,[23] thereby reducing the immunological support of antiretroviral therapy.[24]

Food insecurity, defined as "the uncertain or limited availability of nutritionally adequate or safe food or the inability to procure food in socially acceptable ways," [25,26] is prevalent in low-income households and has been linked to smoking in the general population.[27,28] Food insecurity affects 12% of American households and 16% of households with a child under eighteen.[29] Food insecurity is more prevalent among households led by women and women living alone, ethnic and racial minorities, and households with children (compared to the general US prevalence).[29]

Estimates of food insecurity among PLHIV range from 20-50%,[30,31] with higher prevalence among WLWH compared to their male counterparts.[32,33] Food insecurity among PLHIV is associated with decreased mental and physical health status,[34] suboptimal adherence to antiretroviral therapy,[35] use of illicit substances,[36] and increased HIV-related morbidity and HIV mortality.[37] Important limitations in the studies investigating smoking among PLHIV include that they were conducted among predominately male populations living with HIV,[38-40] lacked granularity in the smoking variable,[38,40] or did not examine smoking severity.[39,40] Given that tobacco use is the most important preventable cause of excess mortality worldwide,[1,2] with increased health consequences to PLHIV and WLWH specifically, expanding our understanding of the role of food insecurity as a potentially modifiable factor among WLWH is vital to reducing these health disparities. Therefore, we conducted an analysis of data from the Women's Interagency HIV Study (WIHS) to understand the associations between food insecurity and smoking over time. We hypothesized that: 1) greater severity of current food insecurity would be associated with higher odds of being a current smoker, 2) change in food security status over time would be associated with change in smoking status, and 3) greater severity of current food insecurity would be associated with higher intensity of smoking.

Methods

Data

Data for this study originated from the WIHS, a longitudinal cohort study of WLWH and demographically similar HIV seronegative controls in the United States (US) that began in 1993 and enrolled women over four recruitment waves in 1994-1995, 2001-2002, 2011-2012, and 2013-2015. The recruitment wave of 2001-02 prioritized the recruit of younger participants, and in those with HIV, participants who were ART-naive, while the 2011-12 wave was to replace participants who had died in the interim. From 2013-2015, four new sites in the Southern US were added to enroll women representative of the distribution of the HIV epidemic in the U.S..[41-43] Recruitment methods are described in detail elsewhere;[42] in brief, women were recruited from HIV care clinics, churches, HIV community organizations, and social-service agencies. For the duration of this study, the WIHS collected socio-behavioral, biological, and clinical data from all participants during semi-annual visits using interviewer-administrated standardized instruments, physical exams, and standard phlebotomy. The physical examination includes standard anthropometry, weight, and a gynecologic examination. Immunologic and virologic biomarker measurements included current CD4 count and HIV RNA viral load.

Beginning in 2013, the Food Insecurity Sub-Study added data on comprehensive measures of food security, dietary intake, household savings, and food support among all WIHS women at nine sites: Bronx, NY; Brooklyn, NY; Washington, D.C.; Chicago, IL; San Francisco, CA; Chapel Hill, NC; Miami, FL; Birmingham, AL/Jackson, MS; and Atlanta, GA. During the Sub-Study period, there were 12,464 person-visits in total in the WIHS among 2,613 unique women. Of these person-visits, 608 were abbreviated visits during which women only contributed lab specimens. During the sub-study period, 317 women were deactivated or disenrolled from the WIHS, mainly due to death (110, 34.4%) or unenrollment due to a site losing funding (Brooklyn only; 114, 36.6%). The rest were due to participant's decision (10%), site's decision (3.4%), or travel reasons (16.7%). The analyses in this paper used data on 11,692 person- visits from 2,553 unique women in total (1,803 living with and 750 without HIV collected from April 2013 to March 2016 at every semi-annual visit). Of these women, 1,689 had been recruited prior to the newest recruitment wave and could therefore contribute up to 6 visits in total during the Sub-Study period; the median number of visits attended was 6 (interquartile range [IQR]: 5, 6). The remaining 864 women were recruited or transferred to the Southern sites during the latest recruitment wave occurring contemporaneously with our Sub-Study. These women could contribute between 2 and 5 visits; the median number of visits attended was 4 (IQR: 3, 4). Participants provided written informed consent and were compensated for participation. This study was approved by the Institutional Review Board at each study site's institution and by the WIHS Executive Committee.

Measures

Exposure: The exposure was food insecurity, measured using the US Department of Agriculture's Household Food Security Module (HFSSM).[44] The HFSSM has been validated in high-resource settings among both vulnerable populations[45,46] and those living with HIV, and is the reference measure of food security in the US.[47] The HFSSM includes 18 items about insufficient food quantity, low diet quality, uncertainty about food, and food affordability.[45] The HFSSM uses recall periods of twelve months and 30 days; the WIHS module was worded to ask about food security over the previous six months or since the last WIHS visit. The HFSSM scoring algorithm categorizes individuals as having high, marginal, low, or very low food security.[47] The HFSSM was available for 98.6% of respondents who were offered the food insecurity sub-study (i.e., did not have abbreviated visits), thus no missing data methods were used for the exposure variable. Cronbach's alpha for the HFSSM in this sample was 0.91, indicating high internal consistency.

Primary outcomes: The primary outcomes were 1) current cigarette smoking status (smoker vs. non-smoker) and 2) smoking intensity (number of cigarettes/day). Both outcomes were assessed by self-report at each visit during the interviewer-administered interview. Participants were asked "Since your study visit on

[previous study visit date], have you smoked cigarettes?" Among those who responded yes, they were further prompted to recall how many cigarettes on average they smoked per day. Given the non- normal distribution of cigarettes smoked per day, the values above zero for this variable were transformed by the natural logarithm. Those who reported zero cigarettes per day were not transformed and were retained as being left-censored. Complete smoking data was available for 99.5% of respondents of the food insecurity sub-study module, thus no missing data methods were used for the outcome. Per WIHS protocol, all participants who reported current smoking were subsequently referred to a smoking cessation program.

Covariates: Covariates were selected *a priori* based upon review of the literature regarding food security and smoking. Covariates were HIV status (seropositive or seronegative [reference group]), age at visit (per year at visit), race/ethnicity (non-Hispanic white [reference group], non-Hispanic African-American/Black, Hispanic, and non-Hispanic other), annual household income as collected by WIHS (≤$12,000 [reference group], $12,001-$24,000, $24,001-$36,000, $36,001-$75,000 and ≥$75,001), employment status (employed [reference group] or unemployed), marital status (partnered [reference group], divorced/widowed/separated, never married, or other), educational attainment (less than high school education [reference group] or greater than a high school education or equivalent), and if they had child dependents < age 18 in the household (none [reference group] or yes). Response options were in reference to the previous six months. Covariate data was missing from 373 unique person-visits (3.2% of person-visits), thus no missing data methods were used.

Given that food insecurity is associated with several mental health outcomes including depression,[34] anxiety and stress,[48] and illicit substance use,[36] and there is likely a bidirectional association between smoking and mental health,[49,50] mental health may be a mediator rather than a confounder on the path from food insecurity to smoking outcomes. Therefore, we did not adjust for mental health variables, as these could potentially be on the causal path from food insecurity to smoking outcomes.

Analysis

Summary statistics were obtained for food insecurity, the smoking outcomes, and all covariates at study baseline (i.e., the first visit during the Food Insecurity Sub-Study). We used a logistic regression model with one cross-sectional sample at the first measure of food insecurity (food insecurity sub-study baseline) to assess the association between food security status and the odds of being a current smoker (hypothesis 1). We also modelled an interaction term between food security and HIV status to assess whether food security in the presence of HIV-seropositivity was associated with differential odds of smoking compared to food secure, HIV-seronegative women. Next, we used a longitudinal logistic regression model with fixed effects for individuals to assess the association between changes in food security status and the odds of becoming a current

smoker compared to becoming a non-smoker (hypothesis 2). This model ruled out potential confounding by unobserved or observed time-invariant characteristics. The fixed-effects model removed all individuals who did not have a change in smoking status over the study visits, allowing us to examine just those who had a change in smoking status and leaving a sample of 344 women (comprising 1,700 person- visits). Given that this model removes person-to-person variability, it allows for the interpretation of change as effects are generated only by those who experience any change. The coefficients from this model are interpreted as adjusted odds ratios. Finally, we used longitudinal Tobit regression to model the association between food security and smoking intensity (natural logarithm of cigarettes/day) (hypothesis 3). Tobit models allow for censoring and were thus implemented given that a large proportion of the values for cigarettes per day were left-censored as over half of women in the sample were non-smokers. Given that cigarettes per day was transformed to the logarithmic scale, the results from the Tobit model are presented as exponentiated coefficients and interpreted as a relative difference (i.e., multiplicative factor) compared to the reference category. All analyses were conducted using Stata 15 (College Station, TX: StataCorp LP).

Patient and public involvement

There was no patient or public involvement in the development of the research questions or in the analyses.

Results

At the Food Insecurity Sub-Study baseline, 42% of women reported being current smokers and 44% reported any category of food insecurity (Table 1). Among current smokers, the median number of cigarettes smoked per day was five (interquartile range [IQR]: 3, 10). The median age of women was 48 years (IQR: 40, 54) and women were predominantly HIV-seropositive (71%), and of African American/Black race (72%), followed by Hispanic women (15%). Nearly two thirds of the women reported an education equivalent to or greater than high school (67.4%) and were unemployed at baseline (65%). Over half had annual household incomes less than $12,000.

In the unadjusted model which included 2,228 women, marginal, low, and very low food security was associated with 1.64 (95% confidence interval [CI]: 1.26, 2.14), 1.90 (95% CI: 1.46, 2.48) and 2.44 (95% CI: 1.84, 3.23) times greater odds of being a current smoker (Table 2). In the adjusted model among 2,133 women, current marginal, low, and very low food security was associated with 1.52 (95% C: 1.14, 2.04), 1.70 (95% CI 1.28, 2.27), and 1.91 (95% CI 1.42, 2.59) times greater odds of being a current smoker compared to those

with high food security (all p<0.01; Table 3). HIV-seropositivity was associated with lower odds of being a current smoker (adjusted odds ratio [AOR]: 0.66; 95% CI 0.53, 0.81, p<0.001). The association between food security status and current smoking was not modified by HIV status (not shown).

In the longitudinal individual fixed-effects model, becoming of marginal, low, and very low food security status was associated with 1.49 (95% CI: 1.04, 2.13), 1.77 (95% CI: 1.17, 2.67), and 1.62 (95% CI: 1.01, 2.58) times greater odds of becoming a current smoker, respectively, compared to becoming a non-smoker (Table 2). In adjusted models, becoming marginal, low, and very low food security were associated with 1.56 (95% CI: 1.08, 2.25), 1.88 (95% CI: 1.23, 2.87), and 1.66 (95% CI: 1.02, 2.81) times greater odds of becoming a current smoker, respectively, compared to becoming a non-smoker (Table 3). In the adjusted model, none of the other time-varying variables were significantly associated with becoming a current smoker.

In the final model for smoking intensity, all study participants were included with nonsmokers censored at zero. The unadjusted relative differences of intensity of smoking (cigarettes/day) were 1.16 (95% CI: 1.07, 1.26), 1.22 (95% CI: 1.11, 1.33), and 1.17 (95% CI: 1.06, 1.30) times higher for women with marginal, low, and very low food security status respectively, compared to those with high food security (Table 2). The adjusted relative differences of intensity of smoking were 1.17 (95% CI: 1.07, 1.27), 1.21 (95% CI: 1.10, 1.32), and 1.16 (95% CI: 1.04, 1.29) times higher for women with marginal, low, and very low food security status, respectively, compared to those with high food security (Table 3).

Discussion

In this longitudinal study of WLWH and demographically similar women without HIV, food insecurity was associated with greater odds of being a current cigarette smoker, with higher odds of smoking as food insecurity severity worsened. Furthermore, any change in food security status was associated with a change in smoking status, and food insecurity was positively associated with smoking intensity. HIV status did not modify these associations, but HIV-seropositivity was associated with lower odds of being a current smoker and lower intensity of smoking compared to HIV-seronegative participants.

Our findings are consistent with literature on the association between food insecurity and smoking status among the general US population,[28] and among women living with and at risk for HIV who experience housing instability.[51] Our findings are not consistent with the literature among WLWH, who have a higher prevalence of smoking than their HIV-seronegative peers.[52] While the prevalence of smoking in the cohort is relatively high, it is lower among WLWH (39%) than demographically similar HIV-seronegative women (49%, p<0.001). Due to the nature of healthcare in the United States, women living with HIV may have access to more

consistent healthcare compared to their demographically similar HIV- seronegative counterparts, allowing for more opportunities for smoking cessation referrals, which may in part explain the lower prevalence of smoking among WLWH in this study compared to the controls. In the WIHS, all women who reported smoking received information at each visit referring them to external smoking cessation programs. Economically disadvantaged people and ethnic minorities typically have less access to smoking cessation treatment,[53,54] and women in general have less success in smoking cessation in the long term than men.[8] Given that this study was predominantly composed of these populations who are simultaneously understudied among PLHIV in the US, our study fills an important gap in the smoking and PLHIV literature.

Being food insecure was associated with 1.16-1.21 times higher (i.e., 16-21% higher) smoking intensity compared to being food secure, even after controlling for income. Food insecurity may drive higher smoking intensity through two mechanisms. First, food insecurity is a profound stressor that leads to poor mental health[48] which in turn is associated with cigarette smoking.[49,50] Second, tobacco acts as an appetite suppressant via the hypothalamus,[55,56] and food insecure individuals may smoke to cope with hunger.[57,58] Given that measures of food insecurity and smoking intensity were obtained at the same study visit, and time between each visit (six months) was too long to assess directionality by staggering food insecurity and smoking intensity, we cannot determine which was driving the other. The consistency in linking food insecurity with smoking in low-income women living with and at risk for HIV here and in prior studies[51] indicates the importance of addressing this issue.

Smoking intensity, however, did not have a dose response relationship with the severity of food insecurity. Two plausible mechanisms may explain this lack of a dose response relationship. First, being food insecure may coincide with volatility in financial resources, which in turn may affect one's ability to afford highly taxed cigarettes and subsequent smoking intensity but not affect smoking status. That is, people of low socioeconomic status are more likely to respond to increased cigarette taxation by reducing intensity of smoking but not by eliminating consumption of cigarettes compared to those of higher socioeconomic status.[59,60] Second, if food-insecure individuals have access to programs that alleviate but not eliminate food insecurity (allowing them to go from a previously very low food security status to low or moderate) via food banks, pantries, or food stamps, then resources previously dedicated to food may be available for non-essential goods including cigarettes. Nevertheless, the relationship between food security and smoking intensity underscores the importance of integrating food security alleviation programs with smoking cessation programming.

This study was unable to assess food insecurity nor changes in food security status as a predictor of smoking cessation success. Becoming food insecure (compared to maintaining a food secure status) is associated with

lower odds of smoking cessation among smokers and with smoking initiation in non-smokers.[28] Yet, we do not know if a change from being food-insecure to food secure may prompt a reduction or cessation in cigarette smoking, presumably as the appetite-suppressing effects of cigarettes are no longer needed. These valuable data would shed light on the effectiveness of the integration of food insecurity alleviation in smoking cessation programming and could be used for policy development and scaled programming.

The study included a large, geographically diverse sample of women living with and without HIV with similar demographic characteristics. A rich set of information was collected for each woman and models adjusted for appropriate control variables. Nevertheless, several potentially important individual characteristics that were not measured were smoking products and smoking behaviors, family history of smoking, previous cessation attempts, social support, and participation in food insecurity alleviation programs. Given that there were few differences in the longitudinal model (compared to the cross- sectional model) when we were able to control for individual variability, as well as the fixed effects model (which removed measured and unmeasured individual characteristics that do not change over time), the role of these potential confounders may be minimal. Collecting data on smoking intensity is notoriously difficult given variabilities in recalling smoking intensity. The survey questions assessed smoking intensity since the last visit six months earlier; long recall periods present opportunities for recall bias in self-reporting of health data. Likewise, food insecurity was assessed during that same recall period. Food security status may fluctuate on a monthly or weekly basis in households experiencing food or financial scarcity; a recall period of six months may not allow us to evaluate these periodic shifts. Further, we were unable to assess other types of common tobacco use, notably vaping and e-cigarettes, whose prevalence and public health impact are increasing greatly. The development of validated questions that can evaluate tobacco exposure from traditional (i.e., cigarette, chewing tobacco, cigars) as well as new delivery mechanisms (i.e., e-cigarettes, vaping) will facilitate a more accurate measurement of tobacco exposure. This potential misclassification in the exposure could result in biasing the results towards the null, whereby women who are food insecure and exclusive vape users were categorized as non-smokers, yet the paths from food insecurity and tobacco use and addiction potentially remain the same. Furthermore, although the prevalence of self-reported cigarette smoking was not low in the sample, there was little change in status over the assessed study visits, which may have limited estimation of the relationship between changes in smoking status and food security. Lastly, despite recent recruitment efforts to match the demographic profile of women living with HIV in the US,[43] WIHS women may not match the profile of those with incident HIV in the US, notably regarding age, which has implications for the generalizability of this study.

In conclusion, food insecurity was associated with both being a smoker and smoking intensity in this sample

of women living with and without HIV. Smoking has a high attributable risk for preventable deaths in the US and globally, and food insecurity may exacerbate this risk. Even on its own, food insecurity significantly increases persistent morbidity across multiple populations.[61,62] Food insecurity is modifiable and alleviating it should be considered in conjunction with smoking cessation programs. Alleviating food insecurity through augmentation of resources while simultaneously reducing smoking, however, is challenging. For example, alleviating food insecurity in overweight women through resource augmentation has tended to exacerbate excess weight,[63] but a recent randomized control trial has demonstrated that a program that was carefully designed and implemented based on in-depth understanding of women's lives in Costa Rica[64] was effective in simultaneously reducing food insecurity and excess body weight.[65] Therefore, experimental or observational studies of programs to alleviate food insecurity should collect data on recent tobacco initiators or quitters to provide valuable information on the contextual milieu that is related to smoking initiation, duration, intensity, and cessation. With such information, researchers may be able to better identify those at risk for tobacco use initiation as well as design and enhance policies and programs to simultaneously reduce food insecurity and promote smoking cessation.

Contributorship statement:
Planning: SDW, PT, EF; Research and study design: LAS, SDW, EF, PT; data analysis: LAS, EF; data interpretation: LAS, SDW, EF, JH, ER; data collection: LAS, KP, TW, AA, DM, MC, EW, AA, IO, EW, LM, JMT, PT, SDW; All authors reviewed and provided feedback on intellectual content and approved the final version of the manuscript.

Competing Interests:
There are no competing interests for any author.

Funding
This study was funded by a Women's Interagency HIV Study (WIHS) sub-study grant from the National Institute of Mental Health, R01MH095683, a mentoring grant K24AI134326 (Weiser), and a scientist development grant K01DK107335 (Palar). Data in this manuscript were collected by the Womens Interagency HIV Study (WIHS), now the MACS/WIHS Combined Cohort Study (MWCCS). The contents of this publication are solely the responsibility of the authors and do not represent the official views of the National Institutes of Health (NIH). MWCCS (Principal Investigators): Atlanta CRS (Ighovwerha Ofotokun, Anandi Sheth, and Gina Wingood), U01-HL146241; Baltimore CRS (Todd Brown and Joseph Margolick), U01-HL146201; Bronx CRS (Kathryn Anastos and Anjali Sharma), U01- HL146204; Brooklyn CRS (Deborah Gustafson and Tracey Wilson), U01-HL146202; Data Analysis and Coordination Center (Gypsyamber D'Souza, Stephen Gange and Elizabeth Golub), U01-HL146193; Chicago-Cook County CRS (Mardge Cohen and Audrey French), U01-HL146245; Chicago- Northwestern CRS (Steven Wolinsky), U01-HL146240; Northern California CRS (Bradley Aouizerat, Jennifer Price, and Phyllis Tien), U01-HL146242; Los Angeles CRS (Roger Detels and Matthew Mimiaga), U01-HL146333; Metropolitan Washington CRS (Seble Kassaye and Daniel Merenstein), U01- HL146205; Miami CRS (Maria Alcaide, Margaret Fischl, and Deborah Jones), U01-HL146203; Pittsburgh CRS (Jeremy Martinson and Charles Rinaldo), U01-HL146208; UAB-MS CRS (Mirjam- Colette Kempf, Jodie Dionne-Odom, and Deborah Konkle-Parker), U01-HL146192; UNC CRS (Adaora Adimora), U01-HL146194. The MWCCS is funded primarily by the National Heart, Lung, and Blood Institute (NHLBI), with additional co-funding from the Eunice Kennedy Shriver National Institute Of Child Health & Human Development (NICHD), National Institute On Aging (NIA), National Institute Of Dental & Craniofacial Research (NIDCR), National Institute Of Allergy And Infectious Diseases (NIAID), National Institute Of Neurological Disorders And Stroke (NINDS), National Institute Of Mental Health (NIMH), National Institute On Drug Abuse (NIDA), National Institute Of Nursing Research (NINR), National Cancer Institute (NCI), National Institute on Alcohol Abuse and Alcoholism (NIAAA), National Institute on Deafness and Other Communication Disorders (NIDCD), National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), National Institute on Minority Health and Health Disparities (NIMHD), and in coordination and alignment with the research priorities of the National Institutes of Health, Office of AIDS Research (OAR). MWCCS data collection is also supported by UL1- TR000004 (UCSF CTSA), P30-AI-050409 (Atlanta CFAR), P30-AI-050410 (UNC CFAR), and P30-AI- 027767 (UAB CFAR).

Data availability statement:
You may request access to the MACS or WIHS Public Use Data Set (MWCCS public use data set will be available in 2021 at https://airtable.com/shrVDP51W5J2qcNeT), or you may submit a concept sheet in order to have access to the full MWCCS data set, which includes data not available in the PDS such as neurocognitive data, abuse data, healthy aging, etc. Having an approved concept sheet means you will receive assistance in understanding the MWCCS study and the complexity of the MWCCS data; linkage to a MWCCS

liaison who can offer expertise in your area of study; support regarding study design, methodology, and statistical analysis; and access to all summary files.

Ethics Statement:
Institutional Review Boards at each of the following universities or institutions reviewed and approved the study procedures (per the MWCCS overall study director, approval numbers are not available):

- University of Mississippi Medical Center
- University of North Carolina at Chapel Hill
- University of Alabama at Birmingham
- University of Miami
- Emory University

Brooklyn WIHS site
- SUNY Downstate Medical Center
- Kings County Medical Center

Bronx WIHS site
- Montefiore Medical Center
- Beth Israel Medical Center
- Mount Sinai School of Medicine

Chicago WIHS site
- Cook County Health & Hospitals System
- Northwestern University
- Rush University Medical Center
- University of Illinois at Chicago

San Francisco WIHS site
- University of California, San Francisco
- Alameda Health System
- Sutter Health
- Santa Clara Valley Medical Center
- San Mateo Medical Center

DC WIHS site
- Georgetown University
- Montgomery County Department of Health and Human Services
- Inova
- Howard University
- Whitman-Walker Clinic

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Table 1: Sociodemographic characteristics of the sample at first visit in the Food Insecurity Sub- Study, Women's Interagency HIV Study (n=2,553 unique women)

	All women	HIV Seropositive N=1803	HIV Seronegative N=750
	N (%) or median (inter-quartile range [IQR])		
Current food security (FS)			
High	1,419 (55.6)	1006 (55.8%)	413 (55.1%)
Marginal FS	405 (15.9)	287 (15.9%)	118 (15.7%)
Low FS	372 (14.6)	263 (14.6%)	109 (14.5%)
Very low FS	357 (14.0)	247 (13.7%)	110 (14.7%)
Current Smoker	1075 (42.1)	706 (39.2%)	369 (49.2%)
Age at visit, yr (median, IQR)	47.7 (40.4, 53.8)	48.2 (41.3, 54.0)	46.1 (38.1, 53.0)
Race			
Non-Hispanic white	255 (10.0)	196 (10.9%)	59 (7.9%)
Hispanic	377 (14.8)	262 (14.5%)	115 (15.3%)
Non-Hispanic African American/Black	1,829 (71.6)	1290 (71.5%)	539 (71.9%)
Non-Hispanic Other	92 (3.6)	55 (3.1%)	37 (4.9%)
Annual Household Income			
<$12000	1,261 (51.9)	925 (53.7%)	337 (47.5%)
$12001-24,000	541 (22.3)	381 (22.1%)	160 (22.5%)
$24,001-$36,000	267 (11.0)	180 (10.5%)	87 (12.3%)
$36,001-75,000	249 (10.2)	153 (8.9%)	96 (13.5%)
$75001	113 (4.7)	83 (4.8%)	30 (4.2%)
Employed (ref: unemployed)	891 (35.0)	592 (32.9%)	299 (40.0%)
Marital status			
Partnered	762 (30.8)	531 (30.4%)	231 (32.0%)
Divorced/separated/Widowed	660 (26.7)	476 (27.2%)	184 (25.4%)
Never Married	800 (32.4)	577 (33.0%)	223 (30.8%)
Other	250 (10.1)	165 (9.4%)	85 (11.8%)
Education (ref: <high school)			
≥High school education	1719 (67.4)	1204 (66.8%)	515 (68.8%)
Child dependents (ref: No)			
Yes	986 (38.6)	664 (36.8%)	322 (42.9%)

Table 2: Unadjusted associations between food security and smoking outcomes

	Cross-sectional association between food security status & current smoking	Longitudinal fixed-effect model examining changes in food security & current smoking	Longitudinal Tobit model examining food security status & smoking intensity
	OR (95% CI)	OR (95% CI)	Relative difference (95% CI)
Current food security (FS)			
High			
Marginal FS	1.64*** (1.26 - 2.14)	1.49* (1.04 - 2.13)	1.16*** (1.07 - 1.26)
Low FS	1.90*** (1.46 - 2.48)	1.77** (1.17 - 2.67)	1.22*** (1.11 - 1.33)
Very low FS	2.44*** (1.84 - 3.23)	1.62* (1.01 - 2.58)	1.17** (1.06 - 1.30)
Observations	2,228	1,766	11,674
Number of WIHSID	2,228	351	2,553

*** p<0.001, ** p<0.01, * p<0.05

Table 3: Adjusted associations between food security and smoking outcomes

	Cross-sectional association between food security status & current smoking	Longitudinal fixed-effect model examining changes in food security & current smoking	Longitudinal Tobit model examining food security status & smoking intensity
	AOR (95% CI)	AOR (95% CI)	Relative difference (95% CI)
Current food security (FS)			
High	Ref.	Ref.	Ref.
Marginal FS	1.52** (1.14 - 2.04)	1.56* (1.08 - 2.25)	1.17*** (1.07 - 1.27)
Low FS	1.70*** (1.28 - 2.27)	1.88** (1.23 - 2.87)	1.21*** (1.10 - 1.32)
Very low FS	1.91*** (1.42 - 2.59)	1.66* (1.02 - 2.71)	1.16** (1.04 - 1.29)
HIV seropositivity (neg ref.)	0.59*** (0.48 - 0.73)	--	0.57*** (0.46 - 0.71)
Age at visit, years	0.99 (0.98 - 1.00)	0.95 (0.83 - 1.08)	1.01 (1.00 - 1.02)
Race			
Non-Hispanic White	Ref.	--	Ref.
Hispanic	0.59* (0.39 - 0.90)	--	0.54** (0.36 - 0.80)
African American/ Black	1.02 (0.73 - 1.44)	--	0.99 (0.71 - 1.38)
Other	0.77 (0.42 - 1.40)	--	0.60 (0.33 - 1.07)
Income			
<$12000	Ref	Ref	Ref
$12001-24,000	0.78* (0.61 - 0.98)	1.05 (0.73 - 1.52)	0.89** (0.81 - 0.97)
$24,001-$36,000	0.84 (0.60 - 1.17)	1.05 (0.61 - 1.82)	0.82** (0.72 - 0.93)
$36,001-75,000	0.62* (0.42 - 0.93)	2.38* (1.05 - 5.39)	0.80** (0.69 - 0.94)
$75001	0.37** (0.19 - 0.71)	1.94 (0.48 - 7.80)	0.54*** (0.42 - 0.71)
Employed (unemployed ref.)	0.45*** (0.36 - 0.57)	1.47 (0.94 - 2.30)	0.89** (0.81 - 0.97)
Marital status			
Partnered	Ref	Ref	Ref
Divorced/separated/Widowed	0.91 (0.70 - 1.17)	0.68 (0.40 - 1.14)	0.92 (0.82 - 1.03)
Never Married	0.94 (0.74 - 1.19)	0.98 (0.57 - 1.69)	1.00 (0.89 - 1.13)
Other	1.07 (0.76 - 1.51)	0.68 (0.36 - 1.27)	0.92 (0.79 - 1.06)
Education (<high school ref)			
≥High school education	0.54*** (0.44 – 0.66)	--	0.42*** (0.34 - 0.52)
Child dependents (no ref)			
Yes	0.66*** (0.48, 0.73)	0.85 (0.56 - 1.29)	0.91 (0.83 - 1.00)
Observations	2,133	1,700	11,301
Number of WIHSID	2,133	344	2,522

*** p<0.001, ** p<0.01, * p<0.05

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5--6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5-6
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	6-7
		(c) Summarise follow-up time (eg, average and total amount)	6
Outcome data	15*	Report numbers of outcome events or summary measures over time	8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear	8-9

		which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	9-10
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.