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Tobacco use increases risk of food insecurity: An analysis of continuous NHANES data from 1999 to 2014

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ABSTRACT

Tobacco use is a major health disparities issue in the United States; it is much more common in less-educated and lower-income groups. These groups also experience a higher prevalence of food insecurity. Previous studies analyzing the association between tobacco use and food insecurity have focused on only cigarettes. We assessed the relationship between food insecurity and use of cigarettes, alternative tobacco products (cigars, electronic cigarettes, smokeless tobacco), any tobacco product, and multiple tobacco products. Using National Health and Nutrition Examination Survey data from 1999 to 2014, we built multinomial logistic regression models predicting degree of food security (i.e., food security, low food security, very low food security) for use of different tobacco product types, any product, and multiple products. After adjustment, use of any product, relative to no use, was significantly associated with increased odds of both food insecurity outcomes: low (adjusted odds ratio (AOR) = 1.2, 95% confidence interval (CI): 1.0–1.4) and very low (AOR = 1.8, 95% CI: 1.6–2.2) food security. In a separate model, single product use, relative to no use, was significantly associated with increased odds of low (AOR = 1.5, 95% CI: 1.3–1.7) and very low (AOR = 2.2, 95% CI: 1.9–2.6) food security. For multiple product use the magnitude of association was higher for very low food security (AOR = 2.7, 95% CI: 1.8–4.0). The significant associations identified here can inform researchers and policymakers developing interventions to prevent tobacco- and food insecurity-related diseases. To be effective in reducing either health risk, interventions may need to target both tobacco use and food insecurity.

1. Introduction

Declines in cigarette smoking prevalence in the United States over recent decades have not benefitted all Americans equally, making tobacco use a major health disparity issue. Current smoking dropped from 42.4% of adults in 1965 to 14.0% in 2017 (Centers for Disease Control and Prevention Office on Smoking and Health, 2018; Wang et al., 2018). Prevalence of other tobacco product use is lower, but still substantial: in the past 30 days, 3.8% of adults used cigar products, 2.8% used e-cigarettes, and 2.1% used smokeless tobacco (Wang et al., 2018). In addition, 19.3% used any tobacco product and, of those who were current tobacco users, 19.0% used two or more products concurrently (Wang et al., 2018). Troublingly, individuals with low socioeconomic status face a disproportionate burden of tobacco use (Jamal et al., 2018), have greater difficulty quitting (Fernandez et al., 2006), and experience greater morbidity and mortality from tobacco use (Clegg et al., 2009; Henley et al., 2016; Homa et al., 2015; Singh et al., 2011).

Low socioeconomic status is associated with a host of preventable conditions and chronic disease risk factors (World Health Organization, 2005). Subsequently, groups that experience more tobacco use also experience greater food insecurity (FI),[1] defined as a lack of consistent access to enough safe and nutritionally adequate food or the inability to procure such foods through socially acceptable means (Life Sciences Research Office, 1990). FI ranges in severity and is often categorized into two levels: low food security is characterized by difficulty procuring enough food or by a reduction in food quality due to access issues and limited resources, while very low food security is characterized by a reduction in intake by some members of a household and by disruption of typical eating patterns (Coleman-Jensen et al., 2017). In 2016, 12.3% of Americans experienced any FI (Coleman-Jensen et al., 2017). The disparity in prevalence between smokers and non-smokers is striking, however: while only 11.9% of non-smokers

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[1] FI = Food insecurity

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reported any degree of FI in 2010–2011, this figure was 24.4% among smokers (Farrelly and Shafer, 2016).

Both tobacco use and FI pose serious health risks and impose substantial health-related costs. In addition to many types of cancer, tobacco use is associated with respiratory diseases, cardiovascular diseases and poor reproductive outcomes (U.S. Department of Health and Human Services, 2014). Each year, cigarette smoking costs the U.S. government more than $300 billion (U.S. Department of Health and Human Services, 2014; Xu et al., 2015). FI is a risk factor for chronic conditions such as diabetes mellitus (Seligman et al., 2007), poor cardiovascular health (Saiz Jr. et al., 2016), mental disorders (Burke et al., 2016) and anemia (Metallinos-Katsaras et al., 2016). It is estimated that in 2014 the health-related costs associated with FI totaled more than $160 billion (Cook and Poblacion, 2016).

A positive association between cigarette smoking and FI has been documented in several specific populations, including adults, low-income families, and households with and without children, among others (Armour et al., 2008; Cutler-Triggs et al., 2008; Iglesias-Rios et al., 2015; Kim et al., 2017; Kim and Tsoh, 2016; Kim-Mozeleski et al., 2018a; Kim-Mozeleski et al., 2018b), however multiple knowledge gaps remain. Prevalence of cigar and smokeless tobacco use is higher in lower-income and less-educated groups than in higher-income, more-educated groups, although cigarette use prevalence is still highest of the tobacco products (U.S. Department of Health and Human Services, 2014). Similarly, concurrent use of multiple tobacco products is more prevalent among lower-income, less-educated groups (U.S. Department of Health and Human Services, 2016). Yet, little is known about whether the association between tobacco use and FI persists across alternative tobacco products, or if the use of any tobacco product, regardless of type, is associated with FI. Further, risk posed by concurrent use of multiple tobacco products has not yet been explored. To date, most studies have focused on specific study populations and have not focused on identifying confounding or moderating factors. We sought to use a nationally representative sample to assess and characterize the relationship between FI and tobacco product use, including cigarettes, e-cigarettes, cigars, and smokeless tobacco; any product use; and multiple product use.

2. Methods

2.1. Study population

These analyses included adult participants (ages 18 or older) of the National Health and Nutrition Examination Survey (NHANES) from 1999 to 2014 ($N = 47{,}356$). NHANES employs a multi-stage probability sampling design and collects cross-sectional information on a variety of health indicators from a nationally representative sample (Curtin et al., 2013; Curtin et al., 2012; Johnson et al., 2014). Data from each NHANES cycle are released biennially and made publicly available (Centers for Disease Control and Prevention, 2018). The data presented here are from consecutive cycles, from 1999-2000 to 2013–2014. Participation rates vary by cycle, ranging from 70 to 80% (Centers for Disease Control and Prevention, 2015). All NHANES cycles were approved by the National Center for Health Statistics Research Ethics Review Board.

2.2. Tobacco use variables

Cigarette use was characterized by an affirmative response to having smoked 100 or more cigarettes over the lifetime and a response of “every day” or “some days” to the question “do you now smoke cigarettes?” Cigar, e-cigarette, and smokeless tobacco use were characterized by a participant responding that they had used a tobacco or nicotine product “during the past five days,” followed by checking the cigar, e-cigarette, or smokeless tobacco (snuff or chewing tobacco) boxes, respectively. For cigars, smokeless tobacco, and e-cigarettes, information on frequency of use (i.e., use every day, some days, or not at all) was not available for all cycles. To quantify agreement between frequency of use and past five-day use with respect to classifying an individual's “current use,” we calculated the kappa coefficient for cigarettes and found it to be strong (0.91). Subsequently, we used past five-day use to represent current use of cigars, smokeless tobacco, and e-cigarettes. Information on cigarettes, cigars, and smokeless tobacco was collected at each cycle; information on e-cigarette use was not collected until 2013–2014.

We also evaluated the effects of any tobacco product use and poly-tobacco use (polyuse), defined as use of two or more product types. Any tobacco product use was defined as current use of any of the four product types. Polyuse was defined as no use of any product, use of only one product, or use of two or more products. To minimize information loss due to the absence of e-cigarette data for participants prior to 2013, we assumed that no one used e-cigarettes between 1999 and 2012. This assumption was based on low prevalence of use during the first several years of e-cigarette production. Even in 2013–2014, national surveys estimated that only 5.5% of American adults were current e-cigarette users, defined as using an e-cigarette every day or some days, and 1.2% were daily users (Kasza et al., 2017).

2.3. Food security status

FI was measured using the U.S. Household Food Security Survey Module, which is a validated and widely used tool (Economic Research Service, 2012). The survey includes statements about food access and availability, and asks participants to report whether or not and how often they experienced those scenarios. Participants with < 2 affirmative responses were classified as food secure. Participants with ≥ 3 affirmative responses were classified into FI categories according to USDA guidelines: those with 3–5 affirmative responses were classified as having low food security, and those with ≥ 6 affirmative responses were classified as having very low food security (Economic Research Service, 2012).

2.4. Covariates

Covariates considered for the final model were those identified from the literature as potential confounders of the relationship between tobacco use and FI, including gender, educational attainment, race, ethnicity, age, body mass index (BMI), marital status, household size, household income-to-poverty ratio, routine place to go for healthcare, and sexual orientation. When cell sizes were too low (i.e. < 20 individuals) to support the inclusion of a particular covariate in one of the models, the covariate was omitted from model selection.

2.5. Statistical analyses

Statistical analyses were conducted using SAS Version 9.4 (Cary, NC). The appropriate sampling weights (i.e., physical examination sampling weights if the model included BMI category, or interview sampling weights if not) were used while computing descriptive statistics and building multinomial logistic regression models. Unadjusted (raw) associations between independent variables and food security were evaluated using chi-square tests with a Rao-Scott correction for categorical predictors and ANOVA for continuous predictors.

Multinomial logistic regression models predicting low and very low food security, compared to food security, were constructed for each tobacco product, any tobacco product, and polyuse, resulting in six models total. For each model, the analytic sample consisted of individuals with valid responses to all variables included in that model. For the e-cigarette model, the sample was restricted to participants of the 2013–2014 cycle, when e-cigarette information was collected. All product-specific models adjusted for use of any tobacco product other than e-cigarettes and the product of interest. For example, in the

Table 1
Adjusted associations between cigarette use, selected covariates and food security status, and characteristics of the analytic sample: National Health and Nutrition Examination Survey, United States, 1999–2014.

	Analytic sample (N = 20,249)	Food security status n (%)[a]			Adjusted OR (95% CI)[b]	
		Food secure (n = 16,468)	Food insecure		Low food security	Very low food security
			Low food security (n = 2168)	Very low food security (n = 1613)		
Current smoking status (overall) *(R-S[c] = 395.64, dF = 2, p < 0.0001)*						
Yes	5317 (25.7)	3800 (23.1)	779 (37.1)	738 (49.1)	–	–
No	14,932 (74.3)	12,668 (76.9)	1389 (62.9)	875 (50.9)	–	–
Non-Hispanic White (ref.) *(R-S = 332.33, dF = 2, p < 0.0001)*						
Yes	2872 (26.9)	2085 (24.1)	369 (47.8)	418 (59.1)	1.5 (1.2, 1.9)	2.3 (1.8, 2.9)
No	6412 (73.1)	5842 (75.9)	312 (52.2)	258 (40.9)	1.0 (ref)	1.0 (ref)
Non-Hispanic Black *(R-S = 72.43, dF = 2, p < 0.0001)*						
Yes	1185 (27.4)	832 (24.5)	189 (36.2)	164 (40.3)	1.9 (1.4, 2.5)	2.1 (1.6, 2.9)
No	3086 (72.6)	2506 (75.5)	334 (63.8)	246 (59.7)	1.0 (ref)	1.0 (ref)
Mexican American or other Hispanic *(R-S = 24.96, dF = 2, p < 0.0001)*						
Yes	954 (19.7)	655 (18.2)	185 (21.9)	114 (28.9)	2.1 (1.5, 2.8)	2.1 (1.5, 3.0)
No	4130 (80.3)	3157 (81.8)	659 (78.1)	314 (71.1)	1.0 (ref)	1.0 (ref)
Other race, including multi-racial *(R-S = 49.24, dF = 2, p < 0.0001)*						
Yes	306 (21.9)	228 (18.8)	36 (31.1)	42 (55.7)	1.9 (1.0, 3.8)	3.6 (2.0, 6.8)
No	1304 (78.1)	1163 (81.2)	84 (68.9)	57 (44.3)	1.0 (ref)	1.0 (ref)
Current use of other tobacco products *(R-S = 3.03, dF = 2, p = 0.22)*						
Yes	915 (5.2)	732 (5.2)	81 (4.2)	102 (5.8)	0.8 (0.6, 1.2)	1.0 (0.8, 1.4)
No	19,334 (94.8)	15,736 (94.8)	2087 (95.8)	1511 (94.2)	1.0 (ref)	1.0 (ref)
Education *(R-S = 858.51, dF = 6, p < 0.0001)*						
Less than high school	4394 (14.9)	2950 (12.2)	896 (34.8)	548 (28.9)	1.0 (ref)	1.0 (ref)
High school grad	4666 (22.9)	3679 (22.3)	539 (25.1)	448 (29.4)	0.7 (0.6, 0.8)	0.9 (0.8, 1.1)
More than high school, no college degree	6406 (33.2)	5294 (33.1)	577 (31.9)	535 (36.2)	0.7 (0.6, 0.9)	1.0 (0.8, 1.3)
College degree	4783 (29.0)	4545 (32.4)	156 (8.3)	82 (5.5)	0.4 (0.3, 0.5)	0.4 (0.3, 0.6)
Sexual orientation *(R-S = 106.45, dF = 2, p < 0.0001)*						
Non-heterosexual (homosexual, bisexual, something else, not sure)	1203 (5.5)	854 (4.8)	177 (8.5)	172 (11.5)	1.4 (1.1, 1.9)	1.9 (1.5, 2.3)
Heterosexual	19,046 (94.5)	15,614 (95.2)	1991 (91.5)	1441 (88.5)	1.0 (ref)	1.0 (ref)
Household income-to-poverty ratio *(F = 1235.98, dF = 2, p < 0.0001)*[d]						
Mean ± SE	3.04 ± 0.03	3.29 ± 0.03	1.50 ± 0.04	1.33 ± 0.04	0.5 (0.5, 0.5)	0.4 (0.4, 0.5)

[a] Frequencies are unweighted; percentages are weighted.
[b] Odds ratios were adjusted for current cigarette use, current use of other tobacco products, education, sexual orientation, household income-to-poverty ratio, race/ethnicity, and the model included an interaction term for cigarette use, race/ethnicity, and NHANES cycle (not shown) (p-for-interaction = 0.025). The reference category for the outcome was food security.
[c] A chi-square test with a Rao-Scott correction was selected to account for complex sampling design.
[d] Test statistics presented for continuous variables are F-statistics for analysis of variance (ANOVA).

cigarette model this variable would represent a participant's use of cigars or smokeless tobacco. In addition, all but the e-cigarette model adjusted for NHANES cycle. Potential confounders were also included in each model. These were covariates found to be associated with the tobacco use variable (i.e., they showed an unadjusted odds ratio significantly different from 1.0) and with FI. To identify moderators, interaction terms including tobacco product use and each confounder were tested for significance using joint tests.

3. Results

3.1. Cigarettes

Covariates identified for inclusion in the cigarette use model included education, sexual orientation, household income-to-poverty ratio, and race/ethnicity, in addition to use of other tobacco products. The model also included an interaction between race and cigarette use (P-for-interaction < 0.01). The final results of this model are shown in Table 1.

Of the 20,249 participants included in the analytic sample for cigarette use, those who were current smokers were significantly more likely to be food insecure (either having low or very low food security) compared to non-smokers (F = 315.3, P < 0.001). After multivariate adjustment for covariates, among white participants, cigarette use was significantly associated with increased odds of low (adjusted odds ratio (AOR) = 1.5, 95% confidence interval (CI): 1.2–1.9) and very low (AOR = 2.3, 95% CI: 1.8–2.9) food security, compared to food security. Among black participants, this figure was 1.9 (95% CI: 1.4–2.5) for low food security, compared to food security, and 2.1 (95% CI: 1.6–2.9) for very low food security, compared to food security. Among Hispanic, including Mexican-American participants, this figure was 2.1 (95% CI: 1.5–2.8) for low food security, compared to food security, and 2.1 (95% CI: 1.5–3.0) for very low food security, compared to food security. Among participants of other races, including participants who are

Table 2
Adjusted associations between cigar use, selected covariates and food security status, and characteristics of the analytic sample: National Health and Nutrition Examination Survey, United States, 1999–2014.

	Analytic sample (N = 21,120)	Food security status n (%)[a]			Adjusted OR (95% CI)[b]	
		Food secure (n = 17,205)	Food insecure		Low food security	Very low food security
			Low food security (n = 2258)	Very low food security (n = 1657)		
Current cigar use						
(R-S[c] = 11.78, dF = 2, p < 0.01)						
Yes	518 (2.4)	397 (2.3)	50 (2.4)	71 (3.9)	1.0 (0.7, 1.4)	1.6 (1.1, 2.3)
No	20,602 (97.6)	16,808 (97.7)	2208 (97.6)	1586 (96.1)	1.0 (ref)	1.0 (ref)
Current use of other tobacco products						
(R-S = 267.77, dF = 2, p < 0.0001)						
Yes	6131 (28.9)	4500 (26.6)	843 (39.0)	788 (50.8)	1.5 (1.3, 1.7)	2.2 (1.8, 2.6)
No	14,989 (71.1)	12,705 (73.4)	1415 (61.0)	869 (49.2)	1.0 (ref)	1.0 (ref)
Education						
(R-S = 910.08, dF = 6, p < 0.0001)						
Less than high school	4656 (15.1)	3143 (12.4)	942 (35.2)	571 (29.2)	1.0 (ref)	1.0 (ref)
High school grad	4840 (22.9)	3816 (22.2)	563 (25.3)	461 (29.5)	0.5 (0.4, 0.6)	0.7 (0.5, 0.8)
More than high school, no college degree	6657 (33.2)	5523 (33.2)	593 (31.4)	541 (35.8)	0.4 (0.4, 0.5)	0.6 (0.5, 0.7)
College degree	4967 (28.8)	4723 (32.2)	160 (8.2)	84 (5.5)	0.1 (0.1, 0.2)	0.1 (0.1, 0.2)
Race/ethnicity						
(R-S = 360.43, dF = 6, p < 0.0001)						
Mexican American or other Hispanic	5440 (14.4)	4076 (12.5)	909 (30.3)	455 (21.4)	2.4 (2.0, 2.9)	1.7 (1.3, 2.2)
Non-Hispanic white	9525 (67.8)	8146 (70.7)	695 (45.9)	684 (53.7)	1.0 (ref)	1.0 (ref)
Non-Hispanic black	4493 (11.7)	3539 (10.6)	533 (18.0)	421 (19.0)	2.0 (1.6, 2.4)	1.7 (1.4, 2.1)
Other race, including multi-racial	1662 (6.2)	1444 (6.2)	121 (5.8)	97 (6.0)	1.5 (1.1, 2.1)	1.4 (1.0, 1.9)
Marital status						
(R-S = 154.30, dF = 2, p < 0.0001)						
Single-headed household, incl. widowed, divorced, separated, never married	8148 (35.7)	6258 (33.7)	1015 (45.3)	875 (53.0)	1.4 (1.2, 1.6)	1.7 (1.4, 2.1)
Married or living with partner	12,972 (64.3)	10,947 (66.3)	1243 (54.7)	782 (47.0)	1.0 (ref)	1.0 (ref)
BMI category						
(R-S = 52.39, dF = 6, p < 0.0001)						
Underweight	523 (2.4)	408 (2.2)	62 (3.1)	53 (3.6)	1.4 (1.0, 2.0)	1.4 (1.0, 2.0)
Normal weight	6214 (31.0)	5170 (31.5)	586 (27.5)	458 (29.2)	1.0 (ref)	1.0 (ref)
Overweight	6836 (32.5)	5664 (33.1)	697 (30.2)	475 (27.2)	1.0 (0.8, 1.2)	0.9 (0.8, 1.1)
Obese	7547 (34.1)	5963 (33.2)	913 (39.2)	671 (40.0)	1.2 (1.0, 1.4)	1.2 (1.0, 1.5)
Routine place to go for healthcare						
(R-S = 186.66, dF = 2, p < 0.0001)						
Yes	16,905 (82.3)	14,111 (83.9)	1584 (70.6)	1210 (74.2)	0.6 (0.6, 0.7)	0.7 (0.6, 0.9)
No	4215 (17.7)	3094 (16.1)	674 (29.4)	447 (25.8)	1.0 (ref)	1.0 (ref)
Sexual orientation						
(R-S = 108.56, dF = 2, p < 0.0001)						
Non-heterosexual (homosexual, bisexual, something else, not sure)	1244 (5.4)	893 (4.8)	177 (8.1)	174 (11.3)	1.5 (1.2, 2.0)	2.0 (1.6, 2.5)
Heterosexual	19,876 (94.6)	16,312 (95.3)	2081 (91.9)	1483 (88.7)	1.0 (ref)	1.0 (ref)

[a] Frequencies are unweighted; percentages are weighted.
[b] Odds ratios were adjusted for current cigar use, current use of other tobacco products, education, race/ethnicity, marital status, BMI category, having a routine place to go for healthcare sexual orientation, and NHANES cycle (not shown). The reference category for the outcome was food security.
[c] A chi-square test with a Rao-Scott correction was selected to account for complex sampling design.

multiracial, cigarette use was not significantly associated with low food security, but was significantly associated with very low food security (AOR = 2.3, 95% CI: 1.8–2.9). Current use of other tobacco products was not significantly associated with FI.

3.2. Cigars

Covariates identified for inclusion in the cigar model were education, race/ethnicity, marital status, BMI category, having a routine place to go for healthcare, sexual orientation, and current use of other tobacco products. Significant interaction terms were identified, however low cell counts (i.e., < 30) resulted in unstable estimates, and these terms were ultimately dropped. The final results of this model are shown in Table 2.

Of the 21,120 participants included in the analytic sample for cigar use, cigar users were significantly more likely than non-users to be food insecure (F = 4.6, P < 0.01). After adjustment for covariates, cigar use was significantly associated with increased odds of very low food security (AOR = 1.6, 95% CI: 1.1–2.3).

3.3. E-cigarettes

Covariates identified for inclusion in the e-cigarette model were marital status, having a routine place to go for healthcare, household income-to-poverty ratio, and current use of other tobacco products. No interactions were identified. The final results of this model are shown in Supplementary Table 1. Of the 4729 participants included in the analytic sample, e-cigarette users were more likely than non-users to be food insecure (F = 9.4, P < 0.01). After multivariate adjustment for selected covariates, e-cigarette use was not significantly associated with FI.

3.4. Smokeless tobacco

Covariates identified for inclusion in the smokeless tobacco model were race/ethnicity, BMI category, having a routine place to go for

Table 3
Adjusted associations between any current tobacco use, selected covariates and food security status, and characteristics of the analytic sample: National Health and Nutrition Examination Survey, United States, 1999–2014.

	Analytic sample (N = 19,965)	Food security status n (%)[a]			Adjusted OR (95% CI)[b]	
		Food secure (n = 16,252)	Food insecure		Low food security	Very low food security
			Low food security (n = 2128)	Very low food security (n = 1585)		
Any tobacco use						
(R-S[c] = 297.35, dF = 2, p < 0.0001)						
Yes	5973 (29.9)	4367 (27.5)	813 (39.8)	793 (52.6)	1.2 (1.0, 1.4)	1.8 (1.6, 2.2)
No	13,992 (70.1)	11,885 (72.5)	1315 (60.2)	792 (47.4)	1.0 (ref)	1.0 (ref)
Education						
(R-S = 869.77, dF = 6, p < 0.0001)						
Less than high school	4292 (14.7)	2882 (12.0)	879 (34.8)	531 (28.7)	1.0 (ref)	1.0 (ref)
High school grad	4558 (22.8)	3592 (22.2)	525 (24.9)	441 (29.4)	0.7 (0.6, 0.8)	0.9 (0.8, 1.1)
More than high school, no college degree	6334 (33.2)	5235 (33.1)	568 (31.9)	531 (36.3)	0.7 (0.6, 0.8)	1.0 (0.8, 1.2)
College degree	4781 (29.2)	4543 (32.6)	156 (8.4)	82 (5.6)	0.4 (0.3, 0.5)	0.3 (0.2, 0.5)
Race/ethnicity						
(R-S = 350.53, dF = 6, p < 0.0001)						
Mexican American or other Hispanic	4990 (13.9)	3751 (12.1)	823 (29.1)	416 (20.7)	1.7 (1.4, 2.0)	1.2 (0.9, 1.5)
Non-Hispanic white	9200 (68.6)	7857 (71.4)	672 (46.5)	671 (54.5)	1.0 (ref)	1.0 (ref)
Non-Hispanic black	4211 (11.5)	3293 (10.4)	516 (18.6)	402 (18.7)	1.5 (1.2, 1.9)	1.2 (1.0, 1.5)
Other race, including multi-racial	1564 (6.0)	1351 (6.1)	117 (5.9)	96 (6.1)	1.4 (1.0, 1.9)	1.3 (0.9, 1.7)
Marital status						
(R-S = 163.63, dF = 2, p < 0.0001)						
Single-headed household, incl. Widowed, divorced, separated, never married	7665 (35.5)	5864 (33.4)	966 (46.2)	835 (52.8)	1.1 (1.0, 1.3)	1.3 (1.1, 1.6)
Married or living with partner	12,300 (64.5)	10,388 (66.6)	1162 (53.8)	750 (47.2)	1.0 (ref)	1.0 (ref)
Sexual orientation						
(R-S = 105.89, dF = 2, p < 0.0001)						
Non-heterosexual (homosexual, bisexual, something else, not sure)	1182 (5.4)	841 (4.8)	171 (8.4)	170 (11.5)	1.4 (1.1, 1.8)	1.8 (1.4, 2.3)
Heterosexual	18,783 (94.6)	15,411 (95.2)	1957 (91.6)	1415 (88.5)	1.0 (ref)	1.0 (ref)
Household income-to-poverty ratio						
(F = 1272.14, dF = 2, p < 0.0001)[d]						
Mean ± SE	3.05 ± 0.03	3.30 ± 0.03	1.50 ± 0.04	1.33 ± 0.04	0.5 (0.5, 0.5)	0.5 (0.4, 0.5)

[a] Frequencies are unweighted; percentages are weighted.
[b] Odds ratios were adjusted for current use of any tobacco product, education, race/ethnicity, marital status, sexual orientation, household income-to-poverty ratio, and NHANES cycle (not shown). The reference category for the outcome was food security.
[c] A chi-square test with a Rao-Scott correction was selected to account for complex sampling design.
[d] Test statistics presented for continuous variables are F-statistics for ANOVA.

healthcare, sexual orientation, and current use of other tobacco products. Two significant interaction terms were identified but subsequently dropped due to small cell sizes. The final results of this model are shown in Supplementary Table 2. After multivariate adjustment for selected covariates, current smokeless tobacco use was not significantly associated with FI.

3.5. Any tobacco product

Covariates identified for inclusion in the any tobacco use model were education, race/ethnicity, marital status, sexual orientation, and household income-to-poverty ratio. A significant interaction between any tobacco product use and marital status was identified, however the difference in estimates was not meaningful, and the term was dropped. The final results of this model are shown in Table 3.

Of the 19,965 participants included in the analytic sample, tobacco product users were more likely to be food insecure than non-users (F = 232.2, $P < 0.001$). After multivariate adjustment for selected covariates, use of any tobacco product was significantly associated with increased odds of low (AOR = 1.2, 95% CI: 1.0–1.4) and very low (AOR = 1.8, 95% CI: 1.6–2.2) food security, compared to food security.

3.6. Polyuse

Covariates identified for inclusion in the polyuse model were education, race/ethnicity, marital status, and household income-to-poverty ratio. Two significant interaction terms were identified but not included due to low cell counts. The final results of this model are shown in Table 4.

Of the 40,905 participants included in this analytic sample, those reporting use of two or more tobacco products were more likely to be food insecure than those using zero or one tobacco product (F = 424.3, $P < 0.001$). The most commonly reported combination of products was cigarettes and cigars (47.9% of polyusers). After multivariate adjustment for selected covariates, the association between use of two or more products and very low food security was statistically significant (AOR = 2.7, 95% CI: 1.8–4.0), and the association between use of two or more products and low food security was marginally significant (AOR = 1.5, 95% CI: 1.0–2.2). Use of only one product was significantly associated with increased odds of low (AOR = 1.5, 95% CI: 1.3–1.7) and very low (AOR = 2.2, 95% CI: 1.9–2.6) food security, compared to food security.

4. Discussion

Our analyses identified a 1.5- to 2-fold increase in the odds of low food security and a 2- to 3-fold increase in the odds of very low food security among current cigarette smokers, stratified by racial/ethnic group. These results are consistent with previous studies. Among Latinos, cigarette smoking was associated with roughly a 1.5-fold increase in the odds of FI (Iglesias-Rios et al., 2015). Among households with children, presence of a smoker at home was associated with a 2-

Table 4
Adjusted associations between current polyuse (3-level), selected covariates and food security status, and characteristics of the analytic sample: National Health and Nutrition Examination Survey, United States, 1999–2014.

	Analytic sample (N = 40,905)	Food security status n (%)[a]			Adjusted OR (95% CI)[b]	
		Food secure (n = 17,205)	Food insecure		Low food security	Very low food security
			Low food security (n = 2258)	Very low food security (n = 1657)		
Current polyuse (3-level)						
(R-S[c] = 526.57, dF = 4, p < 0.0001)						
2 or more products	361 (1.0)	253 (0.9)	48 (1.6)	60 (2.8)	1.5 (1.0, 2.2)	2.7 (1.8, 4.0)
1 product	9207 (24.7)	7011 (22.7)	1153 (34.7)	1043 (45.9)	1.5 (1.3, 1.7)	2.2 (1.9, 2.6)
0 products	31,337 (74.3)	27,222 (76.4)	2621 (63.7)	1494 (76.4)	1.0 (ref)	1.0 (ref)
Education						
(R-S = 1108.51, dF = 6, p < 0.0001)						
Less than high school	11,820 (18.5)	8830 (16.1)	1877 (39.4)	1113 (34.2)	1.0 (ref)	1.0 (ref)
High school grad	9678 (24.1)	8113 (23.8)	886 (24.8)	679 (29.3)	0.7 (0.7, 0.8)	0.9 (0.8, 1.1)
More than high school, no college degree	11,209 (30.7)	9678 (30.8)	831 (27.9)	700 (31.8)	0.8 (0.7, 0.9)	1.0 (0.9, 1.2)
College degree	8198 (26.7)	7865 (29.3)	228 (7.9)	105 (4.7)	0.5 (0.4, 0.6)	0.4 (0.3, 0.5)
Race/ethnicity						
(R-S = 658.11, dF = 6, p < 0.0001)						
Mexican American or other Hispanic	10,232 (12.9)	7787 (11.1)	1631 (29.7)	814 (21.8)	2.1 (1.8, 2.5)	1.5 (1.2, 1.8)
Non-Hispanic white	19,172 (69.9)	17,169 (72.6)	1047 (45.6)	956 (53.2)	1.0 (ref)	1.0 (ref)
Non-Hispanic black	8604 (11.1)	6996 (10.1)	934 (18.9)	674 (18.5)	1.7 (1.4, 2.0)	1.3 (1.1, 1.6)
Other race, including multi-racial	2897 (6.1)	2534 (6.1)	210 (5.9)	153 (6.5)	1.3 (1.0, 1.6)	1.3 (0.9, 1.7)
Marital status						
(R-S = 214.79, dF = 2, p < 0.0001)						
Single-headed household, incl. Widowed, divorced, separated, never married	17,430 (37.6)	14,088 (35.9)	1890 (48.7)	1452 (54.0)	1.1 (1.0, 1.2)	1.2 (1.0, 1.4)
Married or living with partner	23,475 (62.4)	20,398 (64.1)	1932 (51.3)	1145 (46.0)	1.0 (ref)	1.0 (ref)
Household income-to-poverty ratio						
(F = 1306.49, dF = 2, p < 0.0001)[d]						
Mean ± SE	2.96 ± 0.03	3.17 ± 0.03	1.45 ± 0.03	1.27 ± 0.03	0.5 (0.5, 0.5)	0.4 (0.4, 0.5)

[a] Frequencies are unweighted; percentages are weighted.
[b] Odds ratios were adjusted for number of tobacco products currently used (0, 1, 2 or more), marital status, having a routine place to go for healthcare, household income-to-poverty ratio, and NHANES cycle (not shown). The reference category for the outcome was food security.
[c] A chi-square test with a Rao-Scott correction was selected to account for complex sampling design.
[d] Test statistics presented for continuous variables are F-statistics for ANOVA.

fold increase in the odds of adults reporting low or very low food security (Cutler-Triggs et al., 2008). Among low-income families, having a head of household or spouse who smoked was associated with a 1.4-fold increase in the odds of reporting household FI (Armour et al., 2008). The converse has held as well. Among socioeconomically disadvantaged young adults, FI was associated with a 1.5-fold increase in the odds of being a current smoker (Kim and Tsoh, 2016). Stratification of our results by race/ethnicity is a likely contributor to differences between our estimates and those of other studies. The discrepancy could also be due in part to inconsistencies in covariate adjustment between studies and in the categorization of FI.

Use of any tobacco product and the number of products used were significantly associated with FI categories. This may be driven primarily by cigarettes, which demonstrated significant associations with low and very low food security, even across race strata. Smokeless tobacco showed no effect, although the small number of users resulted in relatively imprecise estimates. *E*-cigarettes and cigars exhibited little to no effect on low food security and some effect on very low food security. In these three models other tobacco product use was meaningfully associated with FI, reinforcing the importance of cigarettes. Further, polyuse demonstrated a dose-response relationship with FI: single product use was associated with greater odds of FI as compared with no use, and multiple product use was associated with even greater odds of FI compared with no use.

The differences in effects across products could be due to several factors, including the quantity consumed, which is inherent to the type of product, and the average price associated with that type of product. With respect to quantity, products that are used more frequently (i.e., cigarettes, which are smoked more frequently than cigars) will cost a regular user more than products that are used less frequently (Corey et al., 2017). Similarly, products that are used with the same frequency, but are more expensive, will cost a regular user more than products that are less expensive. Research has shown that tobacco expenditures can crowd out spending on other important household needs, such as food (Wang et al., 2006). As cigarette expenditures increase, food budget share and food quality decrease (Block and Webb, 2009). Subsequently, product types that are more expensive or are used more frequently may divert even more funds from the purchase of food and show a stronger association with FI. A similar rationale might be applied to polyuse. Use of more than one product might incur greater costs than use of only one product or no products, thereby diverting additional household funds and showing a stronger association with FI. To explore this mechanism further, future research should evaluate the role of price—including tobacco product taxes—in these associations.

Several points should be considered when interpreting these findings. First, to minimize the chance false negatives, these analyses did not adjust for multiple comparisons. Replication will be critical in confirming the validity of these findings. Second, the conclusions that may be drawn are limited by the cross-sectional nature of the data. For example, research suggests that there may be a bi-directional, or mutually reinforcing, relationship between cigarette smoking and FI and, therefore, that there may be several different biological or social factors at work (Kim-Mozeleski et al., 2018a). However, absent any temporal information, this study was unable to address this potential source of endogeneity. Still, these analyses provide insight into potential risk factors for this association at a given point in time. Future research

should assess the role of these potential risk factors in a longitudinal study. Further, studies evaluating transitions between products as food security status changes could have regulatory implications.

There are also limitations pertaining to the e-cigarette data. The modern e-cigarette was not invented until 2003; it appeared in the U.S. market a few years later, and sales began picking up after 2007 (U.S. Department of Health and Human Services, 2016). Subsequently, e-cigarettes did not exist at the time of data collection for many NHANES cycles, and our analyses included a small number of e-cigarette users compared to other products. To minimize potential misclassification in the e-cigarette model, we limited the sample to participants from the 2013–2014 cycle. The drawback of this was reduced precision. To minimize a loss of information while classifying polyuse, we assumed no e-cigarette use prior to 2013–2014. In the analytic sample for e-cigarettes presented here, the prevalence of past five-day use was 2.5%, which is compatible with current (i.e., use on every day or some days) and daily use estimates from a nationally representative survey in 2013–2014, which were 5.5% and 1.2%, respectively (Kasza et al., 2017).

Limitations notwithstanding, this study is distinguished by a large, nationally representative sample, although some of the findings may not be as generalizable because of missing data. To our knowledge, this is the first study to examine the relationship between alternative tobacco product or multiple tobacco product use and FI. These analyses demonstrated that use of cigarettes and cigars, in addition to use of any product and concurrent use of multiple products, were significantly associated with increased odds of FI. Perhaps most important is the significance of the work, which addresses two important chronic disease risk factors and health disparities. Both tobacco use and FI predominantly affect those of lower socioeconomic status, and the association between these two risk factors is alarming, given that interventions addressing only one factor may prove less effective than interventions addressing both. Future research should explore the effects of tobacco cessation interventions on incidence and reduction of FI, and of food security interventions on tobacco use, in order to inform the development of effective public health programs.

5. Conclusions

We found that any tobacco product use as well as the number of products used were significantly associated with FI, though the association did not extend to all products. Our findings contribute to a growing body of literature highlighting the complex nature of this relationship. This is the first study to assess the association between FI and alternative tobacco product use or multiple tobacco product use. Future research should evaluate interventions that promote cessation or prevent tobacco use with the intent of preventing or alleviating FI. Conversely, studies should evaluate interventions that are designed to prevent or alleviate FI with the intent of facilitating or preventing tobacco use. Targeting tobacco use and FI simultaneously may promote the effectiveness of related interventions.

Declaration of Competing Interest

The authors have no funding or conflicts of interest to disclose.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2019.105765.

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