Longitudinal experience of food insecurity & cigarette use in the early COVID-19 Pandemic, United States

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ABSTRACT

Food insecurity is associated with cigarette smoking, yet little is known about how variability in the experience of food insecurity may relate to patterns of cigarette use. We sought to examine patterns of food insecurity and cigarette use during the COVID-19 pandemic (April 2020-March 2021). We analyzed longitudinal survey data from a nationally representative panel of adults in the United States (N = 7,880) from the Understanding Coronavirus in America Study. The primary independent variable was ten trajectories of food insecurity. Our dependent variable was past 7-day cigarette use (count of days used cigarettes). Poisson regression using generalized estimating equations was run controlling for key covariates. The prevalence of cigarette use on at least one day in the past week was lowest (17.5 %) for those who Remained Food Secure, and highest (57.9 %) among those who Became *Fully* Food Insecure, a group characterized by having high probability of becoming food insecure during the study period. Among those who reported at least one day of cigarette use in the past week, fewer than half (40.1 %) reported sustained use across all waves of the study. Those who Became *Fully* Food Insecure had an incidence rate ratio (IRR) of 1.73 (95 % CI: 1.18, 2.54) compared to those who Remained Food Secure with respect to number of smoking days. While different patterns of food insecurity are related to cigarette smoking at the population level, these results highlight that food insecurity, a key social need, may represent a novel strategy for informing reduction of tobacco use disparities.

1. Introduction

Food insecurity is a social determinant of health that contributes extensively to a range of health disparities (Gundersen and Ziliak, 2015), including those that are tobacco-related (Kim-Mozeleski and Pandey, 2020;21(1_suppl):124S–138S.). Food insecurity occurs when access to enough food for a healthy life is limited by a lack of money or other resources (Coleman-Jensen et al., 2021). Among the numerous health behavior correlates of food insecurity, several epidemiological studies have concluded that food insecurity is independently associated with increased odds of cigarette smoking (Armour et al., 2008; Kim and Tsoh, 2016; Kim-Mozeleski et al., 2019; Farrelly and Shafer, 2017). Further-more, smoking prevalence systematically increases with the severity of

food insecurity in a dose-dependent fashion (Mayer et al., 2019). While the association between any food insecurity and the odds of smoking has been fairly consistent across many prior studies (Kim-Mozeleski and Pandey, 2020;21(1_suppl):124S–138S.), much less is currently known regarding how variations or changes in food insecurity over time has independent impacts on patterns of cigarette smoking behaviors (Kim-Mozeleski et al., 2019). This is an important and developing area of research that can inform reductions in disparities in smoking by focusing on a key policy-relevant social determinant of health and health behaviors.

According to official estimates by the United States (U.S.) Department of Agriculture (USDA), the 2022 prevalence of food insecurity across the U.S. population (12.8 %) was significantly higher than the

10.2 recorded in 2021 and 10.5 % in 2020 (Rabbit et al., 2023). While the 2020–2021 figures indicate no significant overall increases in food insecurity compared to before the novel coronavirus (COVID-19) pandemic (i.e., 10.5 % in 2019) (Coleman-Jensen et al., 2021), food insecurity does tend to be more episodic rather than chronic throughout the year (Rabbit et al., 2023). Temporal variability in food insecurity is generally not captured in official estimates of food insecurity which is commonly measured as a binary or categorical variable based on time-based recall (e.g., past 12 months) (Bickel et al., 2000). Although the research is relatively nascent, it appears that variability in food insecurity can have important impacts on health and health-related behaviors, (Kim-Mozeleski et al., 2019; Hadley and Patil, 2008) with implications for disparities in health outcomes.

Certain population groups, such as racial and ethnic minority households, were disproportionately impacted by food insecurity during the pandemic than the general population (Coleman-Jensen et al., 2021; Ahn and Norwood, 2021; Gundersen et al., 2021; Leddy et al., 2020). To complement studies on the prevalence of pandemic food insecurity, our team used data from a nationally representative longitudinal study involving measurements of food insecurity indicators every two weeks, in which we identified 10 different longitudinal trajectories of food insecurity in the U.S. population during the first year of the COVID-19 pandemic (April 2020 – March 2021) (Kim-Mozeleski et al., 2023). Two-thirds of the population were food secure throughout the first year of the pandemic, while the remaining one-third experienced variable probability of food insecurity that included increases and decreases over time (Kim-Mozeleski et al., 2023). The extent to which these temporal variations, or longitudinal trajectories, in food insecurity impact smoking behaviors during the early part/first year of the pandemic is not yet well understood. Yet, understanding these variations has the potential to inform reductions in tobacco-related health disparities by better elucidating the patterns and role of food insecurity as a social determinant of tobacco use during a period of heightened societal vigilance on respiratory illness coupled with high levels of social and psychological stress brought on by the pandemic (Kalkhoran et al., 2022).

Individuals in food insecure households have greater risk for depression, anxiety, and stress (Arenas et al., 2019; Pourmotabbed et al., 2020). In the initial phases of the pandemic, food insecurity put individuals at greater risk for poor mental health outcomes (Kong et al., 2022). Furthermore, stress relief is one of the most commonly reported reasons for smoking (U.s., 2017), and increased life stressors contribute to socioeconomic disparities in tobacco use (Hiscock et al., 2012; Mulder et al., 2011). Based on the available literature, it is hypothesized that increases in food insecurity are related to more frequent smoking. The psychological stress of experiencing food insecurity (Allen et al., 2017; Becerra et al., 2015; , xxxx), coupled with the appetite-suppressing effects of nicotine (Jo et al., 2002; Benowitz, 2008) may promote the practice of smoking to cope with stress and to manage feelings of hunger (Knowles et al., 2016; Kim-Mozeleski et al., 2022;19(12):7424.), and this may take place in spite of the high financial burden of smoking for people with socioeconomic disadvantage (Kim-Mozeleski et al., 2022;19 (12):7424.; Peretti-Watel and Constance, 2009; Guillaumier et al., 2015).

The current study builds on prior study findings that elucidated multiple longitudinal patterns of early pandemic food insecurity at the population level, beyond binary measurements of food insecurity. It also builds on prior findings showing that transitions in food insecurity spanning the 2008 economic recession independently predicted smoking status, albeit over a period of many years (Kim-Mozeleski et al., 2019). Specifically, the current study aimed to examine how longitudinal patterns of food insecurity that were identified in previous work (Kim-Mozeleski et al., 2023) were independently predictive of cigarette smoking frequency. This area of research has important implications for further understanding the health behavior correlates of food insecurity.

2. Methods

2.1. Data source and analytic sample

Data come from a subset of the Understanding America Study (UAS)—Understanding Coronavirus in America (UAS-Covid)—a nationally representative panel study of approximately 9,500 adults in U.S. households. In brief, UAS is an Internet panel study that uses an address-based probability sampling strategy and was launched in 2014 by the Center for Economic and Social Research at the University of Southern California. UAS-Covid, launched in March 2020, leverages this sample to capture data on economic and health-related indicators during the COVID-19 pandemic in the U.S. UAS-Covid is a longitudinal series of surveys that were administered every 2 weeks (or waves) from March 10, 2020, through March 30, 2021, and then monthly through July 20, 2021, and has since been collected ad hoc. Each survey is approved by the University of Southern California Human Subjects Committee Institutional Review Board (IRB), and all participants provided informed consent before completing their first survey either electronically or on paper. De-identified data are available to researchers upon registration, and this secondary analysis study was exempted by the Case Western Reserve University IRB. More information on the survey methodology and sampling can be found at https://uasdata.usc.edu.

The current study builds on a previous analysis using the UAS-Covid dataset to empirically identify one-year longitudinal trajectories of individual/household food insecurity experienced during the first year of the pandemic (April 1, 2020 – March 30, 2021; N = 7,944[1]). (Kim-Mozeleski et al., 2023) In UAS-Covid, cigarette use questions were asked starting on April 29, 2020 (UAS Wave 4). The analytic sample for the current study comprised 7,880 unique respondents who responded two or more times to the cigarette use questions yielding a total of 136,556 usable surveys. On average, participants completed 17.3 surveys (SD: 6.4) out of 22 maximum possible surveys.

2.2. Measures

2.2.1. Outcome Variable: Cigarette use days

Cigarette use in the past 7 days was measured using the question "Out of the past 7 days, what is your best estimate of the number of days that you smoked all or part of a cigarette?" Participants were given response options of 0–7 days. Any cigarette use days was defined as any reported use of cigarettes on one or more days within the study period April 29, 2020-March 30, 2021. Further, to examine transitions, we categorized cigarette use days across waves into three categories. *Sustained use days* referred to reporting 1 or more days of use in the past 7 days (e.g., any use of cigarettes) across all available waves of data. *Inconsistent use days* referred to reporting 0 use days in some waves (e.g., no use of cigarettes), but 1 or more days of use in other waves (e.g., any use of cigarettes) indicating that the respondent did not consistently use cigarettes over the course of each wave. *No use days* referred to respondents reporting 0 days of use, for all waves of data (e.g., no use of cigarettes).

2.2.2. Primary independent Variable: Food insecurity patterns

Past 7-day household food insecurity was measured using three items adapted from the USDA Food Security Survey (Bickel et al., 2000): 1) "Were you worried you would run out of food because of a lack of money or other resources?" 2) "Did you eat less than you thought you should because of a lack of money or other resources?" and 3) "Did you go without eating for a whole day because of a lack of money or other resources?" Participants were given three response options namely yes,

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[1] Of the N=7,944 respondents included from the previous study[12], n=64 were excluded based on not having responded to two or more waves of data collection, with two or more responses to tobacco use questions.

no, or unsure. "Unsure" was considered an affirmative response based on prior research on social desirability bias when assessing food insecurity (Makelarski et al., 2017). Similar to the 2-item Hunger Vital Sign (Gundersen et al., 2017; Hager et al., 2010), food insecurity was then defined as any affirmative response (yes or unsure) on any of the items. Latent class growth analysis (LCGA) was used to identify and descriptively label trajectories of one-year food insecurity based on the shape of their probability slope. LCGA is a longitudinal cluster analysis using latent (i.e., not directly measured) variables to identify subgroups within a heterogeneous population that follow distinct trajectories. Cluster membership across individuals is then summarized in a nominal variable.

This research focuses on the 10 food insecurity trajectories identified previously (Supplemental Table 1) and briefly summarized here. This includes three classes who reported *no* change in food security status: Remained Food Secure, Remained Elevated (i.e., had a low probability of food insecurity between April 2020 and March 2021), and Remained Food Insecure. Furthermore, there were two classes whose probability of food insecurity increased: Became *Partially* Food Insecure 1 and 2. There were three classes whose probability of food insecurity decreased slowly: Recovering 1, 2, and 3. Lastly, there were two classes whose probability of food insecurity sharply decreased within the first two months of survey administration: Initial Shock 1 and 2. The primary differences between Became *Partially* Food Insecure and Became *Fully* Food Insecure, who shared similar growth curves, was the baseline probability of food insecurity, which was lower for Became *Partially* Food Insecure (0.237) compared to Became *Fully* Food Insecure (0.539). As a result, Became *Fully* Food Insecure had almost 100 % probability of being food insecure by the end of the study period while Became *Partially* Food Insecure had a 65 % probability (Kim-Mozeleski et al., 2023). The differences between those in the Recovering groups was similar in their initial probability of food insecurity with those in Recovering 3 having 98.8 % probability of food insecurity at baseline, Recovering 2 having 81.0 % probability of food insecurity, and Recovering 1 having 73.3 % probability of food insecurity. Both Initial Shock 1 and 2 had baseline probabilities of 64.3 % and 100 %, respectively, at baseline, but within months reported no food insecurity.

2.2.3. Covariates

Mental Health and Stress. Depression and anxiety were measured using the 4-item Patient Health Questionnaire for Anxiety and Depression (PHQ-4) (Kroenke et al., 2009) which asked participants "Over the past fourteen days, how often have you been bothered by any of the following problems?: 1) Feeling nervous, anxious, or on edge, 2) not being able to stop or control worrying, 3) feeling down, depressed or hopeless, 4) little interest or pleasure in doing things." Respondents were given the options: not at all, several days, more than half the days, and nearly every day. Items were measured on a 0 to 3 scale, respectively, and then averaged for a composite score with higher scores representing greater depression and anxiety. Stress was measured using a 4-item Perceived Stress Scale (Cohen et al., 1983) which asked respondents, "In the past fourteen days, how often have you felt:" 1) "That you were unable to control the important things in your life?", 2) "Confident about your ability to handle personal problems?", 3) "That things were going your way?", 4) Difficulties were piling up so high that you could not overcome them?" Respondents were given the options: never, almost never, sometimes, fairly often, and very often. Items 1 and 4 were scored from 0 to 4 for each response option, respectively. Questions 2 and 3 were reverse scored from 4 to 0. Scores for each item were added together with a range of 0 (lowest perceived stress) to 16 (highest perceived stress).

Concurrent Substance Use. Concurrent use of other substances such as cannabis and alcohol were also included due to their common co-occurrence with cigarette use (Roche et al., 2019). Similar to cigarette use, participants were asked about how many days out of the past 7 they "used cannabis products such as marijuana" or "drank alcohol."

Responses were dichotomized into any alcohol use and any cannabis use within the past 7 days.

Sociodemographics. Sociodemographic characteristics included age, binary sex, marital status, race (White or Caucasian, Black or African American, Native American/American Indian or Alaska Native, Asian/ Asian American, Native Hawaiian or Other Pacific Islander, mixed), ethnicity (Spanish, Hispanic or Latino, not Spanish, Hispanic or Latino), educational attainment (high school or less, some college, Bachelor's degree or more), employment status (currently working, on sick or other leave, unemployed-on layoff, unemployed-looking, retired, disabled, other labor force status, mixed), receipt of Supplemental Nutrition Assistance Program (SNAP) benefits, and household composition (married/cohabiting with kids, single with kids, married/cohabiting without kids, single without kids). Sociodemographic factors, with the exception of receipt of SNAP benefits were based on participants' first survey observation which could have been collected between April 29, 2020, through March 2, 2021. Receipt of SNAP benefits were calculated as any receipt within the duration of the study period.

2.3. Analysis

We compared sociodemographic characteristics of the study sample by cigarette use (no past 7-day cigarette use vs. any past 7-day cigarette use). We reported the number of respondents (percentage) for each category and chi-square tests were used to examine differences across the categorical variables. Population-level longitudinal analyses using generalized estimated equations (GEE) were used to examine the impact of food insecurity class/trajectory (primary independent variable) on the number of days smoked cigarettes in the past week (dependent variable) while controlling for covariates. Those who Remained Food Secure were used as the reference class for the primary independent variable. GEE specifications included Poisson distribution with an autoregressive correlation structure. Model estimates were exponentiated to calculate the Incidence Rate Ratio (IRR). While IRR represents the relative difference used to compare the incident cases of a disease, in this context an IRR above one is interpreted as a greater risk of more smoking days. All analyses were weighted to the U.S. general population and conducted using SAS version 9.4 (SAS Institute Inc).

3. Results

Between April 29, 2020 and March 30, 2021, 25.1 % of respondents reported smoking cigarettes on at least one or more days during the study period (e.g., any use of cigarettes) (Table 1). Respondents aged 40 to 59 reported the highest prevalence of smoking any use of cigarettes (28.3 %) compared to other age groups. Native Hawaiian or Other Pacific Islanders (35.2 %), Black or African American respondents (33.6 %) and American Indian or Alaskan Native respondents (33.2 %) reported higher prevalence of smoking any use of cigarettes compared to other racial groups. One third (34.5 %) of respondents who were not married but had children in the household also reported any use of cigarette. Half (51.8 %) of respondents who used cannabis at baseline also used cigarettes during the study period. In terms of smoking prevalence by food insecurity trajectory, smoking prevalence during the study period was lowest at 17.5 % for those who Remained Food Secure, and highest at 57.9 % for those who Became *Fully* Food Insecure.

Among respondents who reported any use of cigarettes, 59.9 % reported inconsistent use, reporting one or more transitions from no use of cigarettesto any use of cigarettes, and 40.1 % reported sustained use, or use of any cigarettes, over the duration of the study period. Those who reported inconsistent cigarette use reported an average of 2.9 transitions (95 % Confidence Interval (CI): 2.8, 3.0; range 1–14). Those who Became *Fully* Food Insecure reported the greatest prevalence of sustained cigarette use (34.1 %) as well as inconsistent cigarette use days (23.7 %) compared to other pandemic food insecurity trajectories (Fig. 1).

Table 1

Baseline Sociodemographic Characteristics of Adults in the United States by Cigarette Use Days, April 29, 2020-March 30, 2021 (N = 7,880).

	Total Sample Characteristics		No Past 7-Day Cigarette Use	Any Past 7-Day Cigarette Use	
	N = 7,880 (100 %)		n = 6,188 (74.9 %)	n = 1,712 (25.1 %)	
	N	%	Prevalence, Row Percentages (%)		p-value
Age					<0.001
18–39 years	2488	41.8	72.0	28.0	
40–59 years	2979	31.2	71.7	28.3	
60 years or older	2405	27.0	83.1	16.9	
Gender					0.935
Female	4682	53.2	74.9	25.1	
Male	3198	46.8	75.0	25.0	
Race					<0.001
White Only	6064	76.3	75.9	24.1	
Black Only	658	12.9	66.4	33.6	
American Indian or Alaska Native Only	178	0.9	66.8	33.2	
Asian Only	422	5.5	82.7	17.3	
Hawaiian or Pacific Islander Only	61	0.3	64.8	35.2	
Mixed	432	4.2	75.7	24.4	
Ethnicity					0.093
Not Spanish/ Hispanic/Latinx	6569	81.0.9	74.6	25.4	
Spanish/Hispanic/ Latinx	1310	18.1	76.7	23.3	
Household Composition					<0.001
Married with Child (ren)	1580	22.3	80.4	19.6	
Not Married with Child(ren)	844	13.3	65.5	34.5	
Married without Child(ren)	2511	31.1	81.3	18.7	
Not Married without Child (ren)	2592	33.2	70.1	29.9	
Educational Attainment					<0.001
High School or Less	1717	37.5	63.0	37.0	
Some College or Associate's Degree	2913	28.4	75.5	24.5	
Bachelor's or More	3248	34.1	87.8	12.3	
Employment Status					<0.001
Currently Working	4327	55.6	78.0	22.0	
Not working-Laid Off or Looking	635	9.1	59.7	40.3	
Other[a]	2913	35.3	74.1	25.9	
Received any SNAP Benefits	1914	27.9	56.3	43.4	<0.001
Other Substance Use at Baseline					
Any Alcohol Use	3722	45.9	72.5	27.5	<0.001
Any Cannabis Use	935	13.3	48.3	51.8	<0.001

Table 1 (*continued*)

	Total Sample Characteristics		No Past 7-Day Cigarette Use	Any Past 7-Day Cigarette Use	
	N = 7,880 (100 %)		n = 6,188 (74.9 %)	n = 1,712 (25.1 %)	
	N	%	Prevalence, Row Percentages (%)		p-value
Age					<0.001
Food Insecurity Class					<0.001
Became *Fully* Food Insecure[b]	101	1.5	42.2	57.9	
Became *Partially* Food Insecure[b]	208	3.1	52.1	47.9	
Remained Food Insecure	216	3.2	51.0	49.0	
Recovering 1	325	4.2	56.6	43.5	
Recovering 2	151	2.6	56.2	43.8	
Recovering 3	86	1.1	52.3	47.1	
Initial Shock 1	324	4.5	69.6	30.4	
Initial Shock 2	273	3.2	72.8	27.3	
Remained Elevated	832	11.6	65.1	34.9	
Remained Food Secure	5364	65.1	82.5	17.5	

[a] Other includes those who reported being on sick or other leave, retired, disabled, other, or mixed employment

[b] Became *Partially* Food Insecure and Became *Fully* Food Insecure shared similar growth curves, but Became *Fully* Food Insecure had 97.7 % probability of being food insecure by the end of the study period while Became *Partially* Food Insecure had a lower probability of 65 % (Supplemental Table 1).

Data were weighted to the U.S. general population; chi-square tests were used to examine differences across the categorical variables.

In the GEE model, those who Became *Fully* Food Insecure had IRR of 1.73 (95 % CI: 1.18, 2.54) indicating a greater number of smoking days compared to those who Remained Food Secure (Table 2). Additional factors associated with greater numbers of days used cigarettes included use of cannabis which was associated with an IRR of 2.02 (95 % CI: 1.67, 2.44), wherein a greater number of days used cannabis was associated with a greater number of days used cigarettes. Higher educational attainment was associated with an IRR of 0.58 (95 % CI: 0.52, 0.65), indicating fewer days of cigarette use compared to those with lower educational attainment.

In a sensitivity analysis including only those whose probability of food insecurity increased or was persistent, findings held such that those who Became *Fully* Food Insecure reported a significantly greater number of smoking days (IRR = 1.64 (95 % CI: 1.04, 2.57)), compared to those who Remained Food Insecure (Supplemental Table 2).

4. Discussion

This study is one of the first to demonstrate how longitudinal variation in the experience of food insecurity is independently associated with patterns of cigarette use. While this research supports and builds on previous findings that food insecurity, in any form, is associated with tobacco use (Kim-Mozeleski and Pandey, 2020;21(1_suppl):124S–138S.), the current findings suggest that different patterns of food insecurity are related to patterns of cigarette smoking at the population level.

Those who Became *Fully* Food Insecure reported a greater number of smoking days even compared to those who Remained Food Insecure or Became *Partially* Food Insecure. This relationship remained after controlling for factors like educational attainment, employment status, and receipt of SNAP benefits which may highlight a form of stress that is unique to either the experience of becoming food insecure itself or becoming food insecure during a period of heightened uncertainty (e.g.,
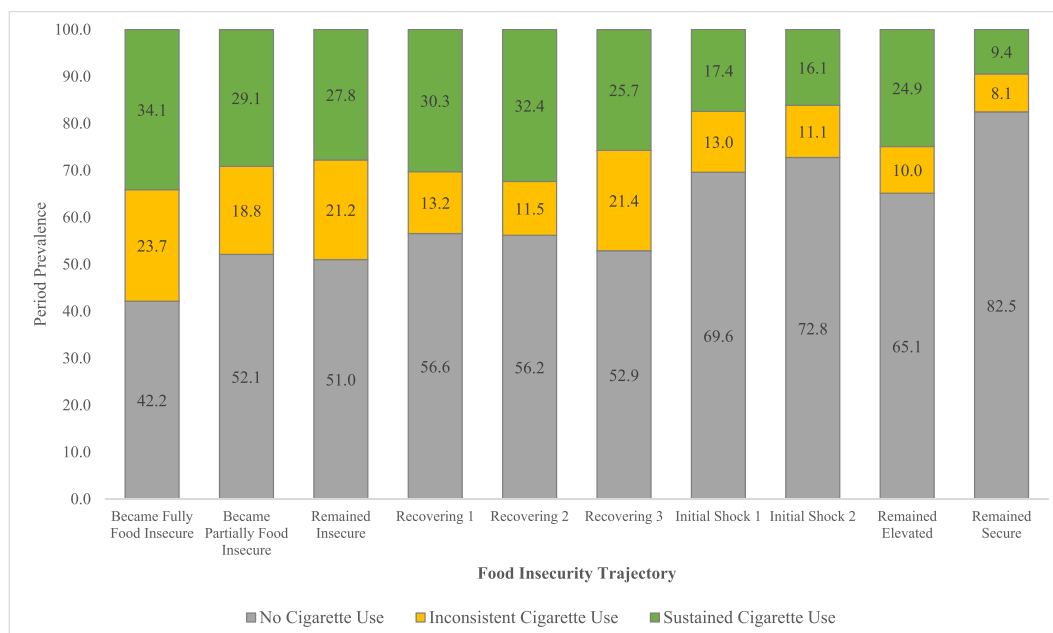
Fig. 1. Patterns of days used cigarettes among adults in the United States (U.S.) by pandemic food insecurity trajectory, April 29, 2020-March 30, 2021 (n = 7,880). Data Notes: Data are weighted to the U.S. general population; Inconsistent cigarette use refers to respondents reporting both use of cigarettes on at least one or more days in the past weekas well as no use of cigarettes in the past week across all observations; Sustained cigarette use refers to use of cigarettes on at least one or more days in the past week use reported across all observations;

COVID-19 pandemic). We note, however, that these findings diverge from a longitudinal study conducted pre-pandemic, showing that older populations who became food insecure report greater smoking cessation. (Bergmans, 2019).

Although the current findings should be considered exploratory, they nevertheless build on previous research (Kim-Mozeleski and Pandey, 2020;21(1_suppl):124S–138S.; Kim et al., 2017) emphasizing the critical need for effective individual as well as structural interventions to address the intersection of food insecurity and tobacco use. Low-income households, where there is a disproportionate prevalence of smoking, also contend with socioeconomic stressors such as food insecurity (Armour et al., 2008). There are complex and reciprocal relationships between smoking and food insecurity (Kim-Mozeleski et al., 2021), which may be particularly important in light of the latest food insecurity estimates by the USDA reporting that population-level food insecurity significantly increased in 2022, compared to 2020 and 2021 (Rabbit et al., 2023). Given the numerous economic drivers of food insecurity, using a systems science perspective in modeling the dynamics of food insecurity with smoking and related health behaviors may provide important implications for health and social policy (Peters, 2014). Furthermore, drawing on methods of community-based system dynamics may identify potential solutions at a more local level (Hovmand, 2014). There is increasing interest among public health researchers in using systems science methods to inform health behavior interventions (Burke et al., 2020).

The current findings have implications for improving upon existing interventions, as food insecurity and other social needs are not typically addressed in the context of smoking cessation interventions. However, a recent study highlighted the promise of offering money management coaching and referral to financial benefits and social services in the context of a smoking cessation program (Rogers et al., 2022). Specifically, among low-income smokers recruited through medical centers, integrating financial coaching and referrals with smoking cessation coaching improved smoking abstinence rates along with reduced stress about finances. Research also supports the acceptability and feasibility of delivering a smoke-free homes intervention through partnership with social services (2–1-1 call centers) among low-income populations

(Thompson et al., 2019). There may be great potential for integrating social and healthcare services to address social determinants of health among low-income people who smoke. Interventions for low-income smokers might connect people with resources to address food insecurity (e.g., assistance with SNAP enrollment, local options for affordable or free food) in addition to addressing the psychological distress that often accompanies food insecurity and promoting stress management. In relation to the current findings, it is recognized that information from food insecurity screenings may not capture critical time periods, such as the transition to experiencing full food insecurity, which presents an important opportunity for future research to improve our ability to screen and identify those who may be at greater risk for becoming food insecure. In tandem with interventions that address smoking cessation and social needs on an individual level, there is a need for more targeted policies and coordinated community and organizational efforts to promote healthy food access and quality healthcare among low-income populations.

This research also showed high prevalence of concurrent cannabis use or co-use of cannabis and tobacco among those experiencing food insecurity across a subsample of U.S. households. The relationship of food insecurity and cannabis use has been previously documented specifically among adolescent and young adult populations (Turner et al., 2022; Nagata et al., 2021) where co-use of tobacco and cannabis is estimated to be between 9 % and 20 % (Reboussin et al., 2021; Cohn et al., 2019). This suggests that the relationship between food insecurity and cannabis, as well as tobacco and cannabis co-use, may exist beyond young adult populations and may warrant further research. Furthermore, in a prior study, co-use of cannabis reduced the odds of successful tobacco cessation at 6-month follow-up by 70 % (Driezen et al., 2022). Higher rates of co-use among those experiencing food insecurity would suggest that successful cessation is even more difficult for a population that is already experiencing multiple forms of vulnerability. Additional research may be warranted to determine if patterns of cannabis use align with tobacco use among this same population.

Table 2

Generalized Estimating Equation Regression Model Fitting For Number of Days Smoked Cigarettes in Past 7 Days by Pandemic Food Insecurity Trajectory Among Adults in the United States, April 29, 2020-March 30, 2021 (n = 6.017).

	B	Standard Error	Incidence Rate Ratio (IRR)	95 % Confidence Limits (IRR)
Intercept	0.72	0.45	2.05	(0.85, 4.95)
Age	0.00	0.00	1.00	(1.00, 1.01)
Gender				
Male	0.14	0.09	1.15	(0.97, 1.37)
Female	Ref			
Race				
Black Only	−0.24	0.14	0.79	(0.60, 1.04)
American Indian or Alaska Native Only	−0.57	0.32	0.56	(0.30, 1.06)
Asian Only	−0.67	0.36	0.51	(0.25, 1.04)
Hawaiian or Pacific Islander Only	−0.50	0.61	0.61	(0.19, 1.99)
Mixed	−0.38	0.22	0.69	(0.45, 1.05)
White Only	Ref			
Ethnicity				
Spanish/Hispanic/ Latinx	−0.59	0.18	0.55	(0.39, 0.79)
Not Spanish/ Hispanic/Latinx	Ref			
Household Composition				
Married with Child (ren)	−0.23	0.13	0.80	(0.62, 1.02)
Not Married with Child(ren)	0.20	0.12	1.22	(0.96, 1.55)
Married without Child(ren)	−0.06	0.11	0.95	(0.76, 1.18)
Not Married without Child(ren)	Ref			
Educational Attainment	−0.54	0.06	0.58	(0.52, 0.65)
Employment				
Not working-laid off or looking	0.28	0.13	1.32	(1.03, 1.69)
Other[a]	−0.16	0.10	0.85	(0.69, 1.04)
Currently Working	Ref			
Receives SNAP Benefits	0.40	0.10	1.49	(1.22, 1.82)
Food Insecurity Trajectory				
Became *Fully* Food Insecure[b]	0.55	0.19	1.73	(1.18, 2.54)
Became *Partially* Food Insecure[b]	0.11	0.22	1.12	(0.72, 1.73)
Remained Food Insecure	0.24	0.22	1.28	(0.83, 1.97)
Recovering 1	0.35	0.17	1.43	(1.02, 2.00)
Recovering 2	0.16	0.25	1.17	(0.72, 1.91)
Recovering 3	−0.02	0.42	0.98	(0.43, 2.24)
Initial Shock 1	0.30	0.16	1.35	(0.99, 1.84)
Initial Shock 2	0.17	0.19	1.19	(0.81, 1.73)
Remained Elevated	0.15	0.14	1.16	(0.89, 1.51)
Remained Food Secure	Ref			
Health Status				
Health	−0.01	0.00	0.99	(0.99, 1.00)
Stress	0.02	0.03	1.02	(0.96, 1.08)

Table 2 (*continued*)

	B	Standard Error	Incidence Rate Ratio (IRR)	95 % Confidence Limits (IRR)
Anxiety and Depression	0.09	0.06	1.10	(0.98, 1.23)
Other Substance Use				
Alcohol Use	0.17	0.09	1.19	(0.99, 1.42)
Cannabis Use	0.70	0.10	2.02	(1.67, 2.44)

[a] Other includes those who reported being on sick or other leave, retired, disabled, other, or mixed employment

[b] Became *Partially* Food Insecure and Became *Fully* Food Insecure shared similar growth curves but Became *Fully* Food Insecure had 97.7 % probability of being food insecure by the end of the study period while Became *Partially* Food Insecure had a lower probability of 65 % (Supplemental Table 1).

Data were weighted to the U.S. general population; Generalized estimated equations (GEE) were used to examine the impact of food insecurity class/trajectory (primary independent variable) on the number of days smoked cigarettes in the past week (dependent variable) on food insecurity class/trajectory (primary independent variable) while controlling for covariates). GEE specifications include Poisson distribution with an auto-regressive correlation structure. Model estimates were exponentiated to calculate the Incidence Rate Ratio (IRR). While the referent is specified for all categorical variables, for all continuous variables (e.g., cannabis use days, alcohol use days, and health status variables), IRR is reflective of a per unit increase.

5. Limitations

This study has limitations that should be considered. Food insecurity status and smoking history prior to or following the first year of COVID-19 pandemic were not considered. As a result, we cannot necessarily conclude that there is a causal relationship between food insecurity and smoking behaviors. Additionally, there is evidence of variability in tobacco use behaviors (e.g., individuals increasing and decreasing tobacco use) as a result of stress and risk perceptions unique to the early COVID-19 pandemic(Bommele et al., 2020) which may limit the generalizability of these findings. Smoking days in the past 7 days also do not capture the intensity of smoking, such as the number of cigarettes used/smoked per day. Furthermore, we recognize that the sample sizes used across food insecurity groups are small particularly compared to those who remained food secure and represent a relatively small proportion of the population. Despite these limitations, the variability in use of cigarettes identified within those experiencing food insecurity highlights an opportunity to improve methods for investigating food security in greater granularity. It also emphasizes the importance of attention to those who may have been most negatively impacted in terms of food insecurity experiences.

6. Conclusion

While the experience of food insecurity overall was associated with a greater number of cigarette smoking days among adults, there was a significantly greater number of cigarette smoking days reported by those who Became *Fully* Food Insecure in the first year of the pandemic even compared to those who experienced food insecurity persistently or those who Became *Partially* Food Insecure. As socioeconomic disparities in the use of tobacco persist, these results highlight the importance of identifying targeted strategies to prevent populations from entering a trajectory towards food insecurity or intervening earlier on.

7. Declaration of competing interest

The authors have no interests to disclose.

CRediT authorship contribution statement

Stephanie Pike Moore: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Douglas D. Gunzler:** Formal analysis, Writing – original draft, Writing – review & editing. **Claire A. Spears:** Conceptualization, Writing – original draft, Writing – review & editing. **Nida I. Shaikh:** Writing – review & editing. **Jin E. Kim-Mozeleski:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2024.102624.

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