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RESEARCH ARTICLE

COVID-19 Vaccine Hesitancy by Smoking Status Among Ohio Adults

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ABSTRACT

Background: Research in other countries and limited findings in the United States suggest that adults who smoke are less likely to get COVID-19 vaccines. The objective of this study was to examine vaccine hesitancy by smoking status in Ohio.

Methods: We performed a secondary analysis of multiple 8-week waves of the Ohio COVID-19 Survey (OCS) from March 2021 to July 2022. The OCS participants comprised a subsample from the 2019 Ohio Medicaid Assessment Survey, a statewide health survey. After the COVID-19 vaccine was available, participants were asked about vaccination status and, among those not vaccinated, vaccine intentions. To compare vaccine hesitancy by smoking status, multivariable survey-weighted logistic regression models were fit, adjusted for potential confounders. Reason for vaccine hesitancy was asked using an open-ended question; data were coded and analyzed descriptively.

Results: Adults who smoked, compared to those who never smoked, had significantly higher odds of being vaccine hesitant between March and April 2021, June and August 2021, October and November 2021, and May and July 2022, with odds ratios ranging from 1.60 to 2.44. Reasons for vaccine hesitancy were not different by smoking status.

Conclusion: Although the difference in hesitancy by smoking status was attenuated after December 2021, coinciding with an increase in cases, evidence from summer 2022 indicates that adults who smoked continued to display vaccine hesitancy. These results have implications for COVID-19-related outcomes and more research is needed to understand reasons for vaccine hesitancy, which could also serve to educate adults who smoke about vaccination for other diseases.

Keywords: COVID-19; Vaccine hesitancy; Smoking; Survey research

INTRODUCTION

The COVID-19 pandemic has brought unprecedented changes in the daily lives of people across the world due to loss of lives, deteriorating physical and mental health, an economic downturn, lack of mobility, and restricted social activities. Amidst the crisis, the development of efficacious vaccines has given the hope of returning to normalcy. Yet, vaccines are most effective in protecting populations when a sufficient number of people are vaccinated.[1,2] In addition, vaccinating high-risk individuals is an important goal.[3] One such high-risk group is tobacco users.

Smoking and COVID-19

The associations between tobacco use and COVID-19 infection and severity have been examined in several studies, with mixed results. For example, in the largest study to date, with over 2 million individuals, Young-Wolff and colleagues reported that current

smoking was associated with lower adjusted rates of COVID-19 infection, hospitalization, ICU admission, and death.[4] Additionally, Simons et al found that individuals who smoked, compared to those who never smoked, had a 26% reduced risk of COVID-19 infection.[5]

Prior literature, however, suggests that there are associations between smoking and risks for symptomatic and severe COVID-19. In a meta-analysis of studies examining smoking and COVID-19 risk, Gülsen and colleagues estimated a 1.5-fold increased risk of symptoms, ICU admission, and mortality among adults who smoked compared to those who never smoked.[6] Former smokers also appear to be at risk for severe COVID-19. In 1 study, veterans who formerly smoked had an increased 30-day mortality risk following COVID-19 infection compared with those who currently smoked and those who never smoked.[7]

The intensity of tobacco use, measured by frequency of use or dual use, appears to increase the risk for symptomatic COVID-19.[8] In a study of adolescent and young adults, dual cigarette and e-cigarette users were 6.8 times as likely to be diagnosed with COVID-19 and 4.7 times as likely to experience COVID-19 symptoms compared to nonusers.[9] In another study of college students, use of multiple tobacco products was associated with 2-fold to 3-fold increased odds of COVID-19 symptoms and diagnosis.[10,11]

Smoking and Vaccine Hesitancy

Because of risks for COVID-19 illness, smokers should be encouraged to get vaccinated to prevent severe COVID-19. However, compared to those who never smoked, those who currently smoke have been found in the past to be vaccine hesitant in general.[12,13] Studies examining hesitancy toward the COVID-19 vaccine are beginning to emerge.[14-17] Jackson et al reported that in the United Kingdom, those who currently smoked were 1.5 to 2 times more hesitant to get the COVID-19 vaccine than those who formerly smoked or never smoked, respectively, with lack of trust and beliefs about corporate profiteering from vaccines being major reasons for vaccine hesitancy.[15] Vaccine hesitancy was also 1.8 times as high among those who smoked in Hong Kong.[16] In Israel, adults who currently smoked had a 10% lower odds of receiving the COVID-19 vaccine compared to nonsmokers.[17] Data from the United States (US) are limited. During the initial rollout of the COVID-19 vaccine in the US (December 2020 – January 2021), Yang and colleagues found no difference in hesitancy between people who smoked or vaped versus nonsmokers or vapers.[14]

Current Study

Vaccine hesitancy is a threat to public health in the US, particularly with the variants that started surging during summer of 2021 and the concern about future variants.[18,19] Vaccine uptake is a critical component of an infectious disease control plan for populations. At the individual level, vaccines are key to preventing severe COVID-19, as unvaccinated individuals are more likely to be hospitalized and die from COVID-19.[20,21] People who smoke are at higher risk for chronic respiratory conditions, such as asthma, chronic obstructive pulmonary disease, and lung cancer.[22] Because their lungs are already vulnerable to disease, adults who smoke should be targeted with additional rigor through public health initiatives, like vaccine drives, or their health care providers to promote vaccine uptake.

To examine trends in vaccine hesitancy among smokers versus nonsmokers in Ohio, we examined data from the Ohio COVID-19 Survey (OCS). The OCS was an ongoing surveillance survey, fielded in biweekly samples, that was representative of adults aged 19 years and over in Ohio and ran from April 2020 through December 2022. The OCS monitored COVID-19 infection and testing, vaccination behavior, and social distancing, as well as employment and insurance status, financial security, and other important physical and mental health outcomes. This study focused on trends in vaccine hesitancy by smoking status in Ohio. We hypothesize that adults who smoke would be more vaccine-hesitant than adults who never smoked. A second objective is to identify reasons for vaccine hesitancy overall and by smoking status.

METHODS

Participants

This study is a secondary data analysis of multiple waves of the OCS. The OCS participants comprise a subsample from the 2019 Ohio Medicaid Assessment Survey (OMAS), a state-level periodic survey that assesses health care access and the health status of Ohio's population, and is weighted to be representative at the statewide and Ohio regional levels.[23] While the survey name includes "Medicaid," respondents were not limited to those enrolled in Medicaid. The 2019 OMAS was designed as a stratified random digit dial telephone (landlines and cell phones) survey which interviewed approximately 32 000 Ohio adults from July to December 2019. The 26 660 OMAS participants who had agreed to be recontacted comprised the sampling frame for the OCS. The OCS targeted 650 interviews for each biweekly sample.

Procedures

The OCS was designed as a rotational panel with weekly samples starting on April 20, 2020. Beginning on September 8, 2020, biweekly samples were fielded. After releasing a rotational sample every other Monday, sample members were sent a series of text messages and emails (if available) with a link to complete the survey by web. If there was no response from the sample member, text/email reminders were followed by calls made by interviewers to complete the survey by phone. The survey took approximately 10 minutes to complete. Survey weights were adjusted to correct for potential panel selection bias so that the design-based weight for each OCS participant fully represents the state population and subpopulations within the state. These weights were recalibrated to the CDC's COVID-19 administrative data vaccine totals for Ohio to further correct for survey nonresponse. The in-

stitutional review board at The Ohio State University determined the secondary use of OCS data to be exempt.

Measures

The primary dependent variable for this analysis was vaccine hesitancy. Beginning in January 2021, after the US Food and Drug Administration (FDA) had approved the Pfizer vaccine for emergency use, the OCS included the following question about COVID-19 vaccine uptake, "Have you ever received a COVID-19 vaccine?" For those who had not yet received the vaccine, there was a follow-up question, "When a COVID-19 vaccine is available to you, how likely are you to get it?" A 4-point response scale of "not likely at all," "not too likely," "somewhat likely," and "very likely" was given. Those who responded 'somewhat likely' or 'very likely' were categorized as nonhesitant whereas those responding 'not too likely' or 'not likely at all' were categorized as vaccine hesitant.

The secondary dependent variable for this analysis was the reason/reasons for vaccine hesitancy. If a participant indicated they were 'not too likely' or 'not likely at all' to receive the COVID-19 vaccine, they were then asked, "In one sentence please explain why you would not get the COVID-19 vaccine." Prior to independent coding, research assistants were trained on how to code the open-ended responses. Several practice rounds were completed. After the coders reached good reliability (Krippendorff's alpha > 0.80), two trained research assistants independently coded each open-ended response for as many themes that were present in the quote. After that, they met and compared responses and discussed any disagreements. Following the discussion, final codes were assigned. The following themes were coded: safety concerns, anti-vaccination feelings in general, lack of trust in the government, concerns about other comorbidities, belief that vaccine is not needed because COVID-19 is not severe or that a prior infection means one does not need the vaccine, vaccine shot may be painful, concerns about access, or other response that does not fit into any of the predetermined themes.

The main independent variable of interest was smoking status of the participants. To identify whether participants were smokers, we relied on their responses to questions about smoking on the 2019 OMAS. We classified the participants as current smokers (smoked at least 100 cigarettes in their lifetime and currently smoked every day or some days), former smokers (smoked at least 100 cigarettes in their lifetime and currently smoked no days at all), and never smokers (did not smoke at least 100 cigarettes in their lifetime).

The other independent variables included in the models were county type (rural Appalachian, rural non-Appalachian, metropolitan, and suburban), age (in years), gender, education status (dichotomized as no college degree and college or above), race and ethnicity (non-Hispanic White, non-Hispanic Black, other), and poverty level (dichotomized as below and at-or-above 138% of the federal poverty level (FPL)).

Analysis

For the primary analysis, data from March 08, 2021, to July 26, 2022, were analyzed, which comprised 9 waves of data collection. For our analysis, we used survey-weighted multivariable logistic regression models to estimate odds ratios (ORs) for the association between smoking and vaccine hesitancy. Models were adjusted for age, gender, race and ethnicity, county type, educational attainment, and poverty level. Confounder identification was conducted using a directed acyclic graph. All analyses accounted for the complex sampling design of the OCS and sampling weights were adjusted when pooling multiple weeks of data. A 2-sided p-value less than 0.05 indicated statistical significance. We ran the analysis on R (Version 4.1.2).[24]

For the secondary analysis of reasons for hesitancy, wave 7, which corresponds to August 9, 2021, through October 3, 2021, was selected to examine the reasons for vaccine hesitancy. To examine the secondary outcome, we compared the reasons for vaccine hesitancy by smoking status using chi-square tests that were corrected for multiple testing using the Bonferroni-Holm method.

RESULTS

Demographic characteristics of participants were consistent across waves (Table 1). The average age of respondents was approximately 42 years, about half were male, approximately 70% of respondents were non-Hispanic White, nearly 30% had at least some college education, between 24% and 29% lived below the FPL, and more than 56% lived in metropolitan areas. COVID-19 vaccination increased from 26.4% in the March 8 to April 18, 2021, period to 75% in the May 16 to July 26, 2022, period. Vaccine hesitancy ranged from approximately 29% to 39%.

Adults who smoked, compared to those who never smoked, had significantly higher odds of being vaccine hesitant in 3 of 6 waves between early March 2021 and late November 2021 (Table 2). These periods coincided with a generally increasing trend in COVID-19 cases in Ohio (Figure 1). December 2021 and January 2022 were characterized by large increases in COVID-19 cases in Ohio, and we did not observe a significant difference in vaccine hesitancy between smokers and nonsmokers. We also did not observe differences coinciding with the decrease in cases between late-January and April 2022. However, adults who smoked had significantly higher odds of being vaccine hesitant between May and July 2022. We did not find a statistically significant difference between adults who formerly smoked and those who never smoked in vaccine hesitancy except for the period between May and June 2022 (Table 2, Figure 1).

Reasons for vaccine hesitancy did not differ significantly by smoking status (Figure 2). Among the 394 vaccine hesitant individuals, most reported being hesitant because of concerns about the vaccine being too new or unsafe, concerns about other comorbidities which could interfere with the vaccine, lack of trust in the govern-

Table 1. Weighted Demographic Characteristics of OCS Sample at Each Wave of Data Collection

	3/8 – 4/18/21 (n = 1262)	4/19 - 6/13/21 (n = 1687)	6/14– 8/8/21 (n = 1773)	8/9 – 10/3/21 (n = 1792)	10/4 - 11/28/21 (n = 1635)	11/29/21 -1/23/22 (n = 1726)	1/24 - 3/20/22 (n = 1668)	3/21 - 5/15/22 (n = 1768)	5/16 - 7/26/22 (n = 1337)
Age (mean [SD])[a]	41.7 [13.5]	41.8 [13.6]	41.8 [13.6]	41.8 [13.6]	41.9 [13.5]	41.9 [13.5]	41.9 [13.7]	41.9 [13.4]	41.9 [13.5]
Race/Ethnicity[a]									
Non-Hispanic White	78.3%	78.5%	78.5%	77.3%	78.5%	78.0%	78.3%	78.0%	78.0%
Non-Hispanic Black	13.2%	12.9%	13.0%	14.1%	12.5%	13.1%	12.6%	12.9%	12.8%
Other	8.5%	8.6%	8.5%	8.6%	9.0%	8.9%	9.1%	9.1%	9.2%
Gender[a]									
Male	49.2%	49.1%	49.2%	49.1%	48.7%	48.9%	48.6%	48.9%	49.0%
Female	50.8%	50.9%	50.8%	50.9%	51.3%	51.1%	51.4%	51.1%	51.0%
Education[a]									
College or above	30.2%	29.3%	29.1%	30.4%	29.5%	29.7%	29.9%	29.6%	29.9%
High school or less	69.8%	70.7%	70.9%	69.6%	70.5%	70.3%	70.1%	70.4%	70.1%
Federal poverty level[a]									
Below	27.9%	29.8%	28.9%	28.7%	28.7%	24.8%	24.9%	26.2%	24.2%
At or above	72.1%	70.2%	71.1%	71.3%	71.3%	75.2%	75.1%	73.8%	75.8%
County type[b]									
Rural Appalachian	14.6%	15.2%	15.3%	13.8%	15.0%	14.3%	14.8%	14.4%	14.2%
Rural non-Appalachian	11.5%	11.3%	12.1%	12.9%	12.6%	12.8%	12.5%	13.3%	12.1%
Suburban	16.7%	16.5%	15.8%	16.3%	16.2%	16.1%	15.9%	15.6%	15.6%
Metropolitan	57.2%	57.0%	56.8%	57.0%	56.2%	56.8%	56.8%	56.7%	58.1%
Smoking status[a]									
Never	54.1%	56.1%	54.4%	53.8%	53.3%	55.6%	55.8%	57.3%	56.8%
Current	24.7%	23.5%	25.5%	26.1%	27.1%	22.9%	24.2%	22.8%	22.7%
Former	21.1%	20.4%	20.1%	20.1%	19.6%	21.5%	20.0%	20.0%	20.5%
Vaccine status[b]									
Yes	26.4%	46.7%	53.0%	57.6%	61.3%	64.8%	67.1%	67.7%	67.4%
No	73.6%	53.3%	47.0%	42.4%	38.7%	35.2%	32.9%	32.3%	32.6%
Vaccine hesitancy[b]									
Yes	37.5%	38.9%	38.5%	34.4%	33.7%	30.1%	29.0%	30.8%	31.2%
No	62.5%	61.1%	61.5%	65.6%	66.3%	69.9%	71.0%	69.2%	68.8%

[a] Source of data: 2019 Ohio Medicaid Assessment Survey.
[b] Source of data: Ohio COVID-19 Survey.

Table 2. Adjusted Odds Ratios (ORs)[a] and 95% Confidence Intervals for Vaccine Hesitancy Associated with Smoking Status at Each Wave of Data Collection

	Smoking status		
OCS wave	**Never (Ref)**	**Former**	**Current**
3/8 – 4/18/21	1.0	1.26 (0.78, 2.04)	**1.98 (1.18, 3.31)**
4/19 – 6/13/21	1.0	1.09 (0.69, 1.70)	1.47 (0.91, 2.38)
6/14 – 8/8/21	1.0	1.00 (0.64, 1.57)	**1.60 (1.04, 2.45)**
8/9 – 10/03/21	1.0	1.21 (0.76, 1.95)	1.27 (0.79, 2.04)
10/04 – 11/28/21	1.0	1.37 (0.85, 2.19)	**1.73 (1.06, 2.82)**
11/29/21 – 1/23/22	1.0	1.34 (0.85, 2.12)	1.37 (0.81, 2.32)
1/24 – 3/20/22	1.0	1.41 (0.85, 2.34)	1.28 (0.74, 2.20)
3/21 – 5/15/22	1.0	1.55 (0.96, 2.52)	1.46 (0.88, 2.44)
5/16 – 7/26/22	1.0	**2.71 (1.58, 4.62)**	**2.44 (1.40, 4.26)**

[a] Boldfaced ORs and Confidence Intervals indicate statistically significant results.

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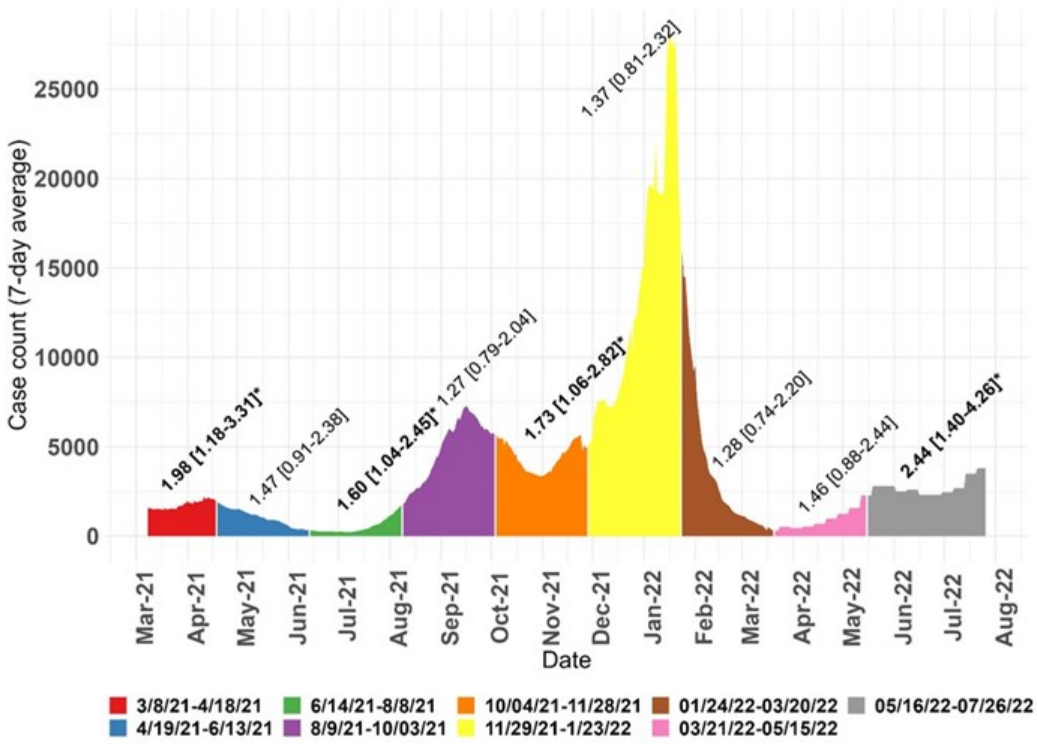

The y-axis of the plot is the 7-day average for COVID-19 case counts for Ohio obtained from the CDC (https://www.nytimes.com/interactive/2023/us/ohio-covid-cases.html).
Colors indicate each wave of the OCS with annotated odds ratio and confidence intervals for the association between smoking and vaccine hesitancy across each wave.

Figure 1. Odds Ratios and 95% Confidence Intervals Comparing Ohio Smokers to Nonsmokers with Respect to Vaccine Hesitancy Over Time, Superimposed Over New Daily COVID-19 Case Counts

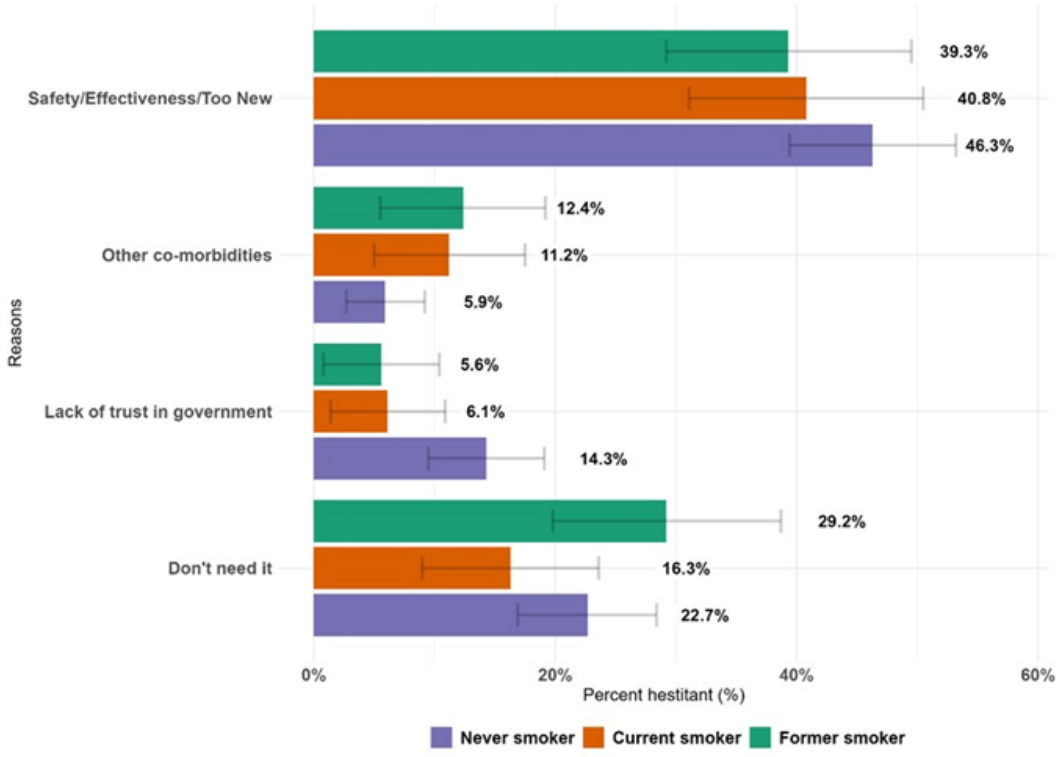

Figure 2. Reported Reasons for Vaccine Hesitancy (8/9/2021 to 10/3/2021)

ment, or a belief that the vaccine was not needed. Sample quotes from these codes are the following:

Vaccine is too new and unsafe:

> *Not enough research has been done; still isn't working for those who have gotten it. I don't trust the system.*
>
> *I don't think they actually know what they're doing it's possible they're giving us COVID-19 or other things. They've made it way too fast.*

Other comorbidities interfere with the vaccine:

> *I have an autoimmune disease and I am also having other issues that they think might be due to COVID.*
>
> *Not ready yet. I have other health issues, and do not want to chance on side effects.*

Lack of trust in the government:

> *My trust is in God not the government.*
>
> *Don't trust the current government. People with the shot are still getting COVID and dying.*

COVID-19 vaccine is not needed:

> *I have no need I am healthy and will be fine.*
>
> *I don't need to because I work from home. I have already had COVID.*

DISCUSSION

We investigated whether adults who smoked and those who did not smoke differed with respect to COVID-19 vaccine hesitancy over a period shortly following expanded vaccine rollout in March 2021 through the summer months of 2022. We found some evidence that in Ohio, adults who smoked were more hesitant to get the COVID-19 vaccine during certain points in the pandemic. The significant difference in vaccine hesitancy based on smoking status mostly coincided with periods of relatively lower COVID-19 cases in Ohio prior to the peak in infections in December 2021 and January 2022.

Consistent with our findings across periods when the vaccine was available to all adults and most children, a study by Shkalim Zemer and colleagues found that Israeli adults who smoked were less likely to receive a COVID-19 vaccine[17] during the time when it was widely available. However, the differences across smoking status we saw across the early months following vaccine rollout were contrary to a finding by Yang and colleagues who reported that at the initial rollout, adults in the US who smoked were not significantly more hesitant compared to those who did not smoke.[14] It is important to note that during the early months of 2021, the eligibility for receiving the COVID-19 vaccines was limited to health care workers and a few other groups.[25] Thus, "hesitancy" was more of a theoretical behavior. It is important to highlight the finding that vaccine hesitancy was significantly greater among smokers during summer 2022. This finding could suggest that COVID-19 vaccine hesitancy is lingering in some groups, such as adults who smoke. Public health professionals should continue to focus vaccination efforts on this group of high-risk individuals.

As COVID-19 continues to cause hospitalizations and deaths in the US, it is important to track vaccine hesitancy to understand which vulnerable groups might need further intervention to promote receipt of 1 of the highly effective COVID-19 vaccines. Adults who smoke are 1 such vulnerable group, as most (but not all) studies have demonstrated that they are at increased risk for severe COVID-19 outcomes.[4-11] Our novel finding that the reasons for being hesitant do not differ by smoking status is important because it suggests that efforts to target hesitant individuals, in general, may not need to be tailored based on smoking status, and instead might focus on other demographic characteristics. The most prominent concern about the COVID-19 vaccine in the OCS was that the vaccine is too new and thus has not been tested enough for safety and effectiveness. This finding is generally supported by other studies which find that concerns about the safety of vaccines, anxiety about efficacy, and a desire for more information, are some of the primary drivers of COVID-19 vaccine hesitancy among adults in China, Portugal, Italy, and the US.[26-30] Another common concern in the OCS was a belief that the vaccine is not needed because COVID-19 is not severe or a misunderstanding that the vaccine is not needed if a person has already had COVID-19. This latter concern, which appears to be driven by misinformation and poor health literacy, is also supported by survey research in the US that finds that the degree of threat perception around the virus is associated with vaccine hesitancy.[31] The prevalent role of fear and misinformation around the COVID-19 vaccines among vaccine hesitant Ohioans indicates the importance of targeting public health education campaigns to address these concerns in particular.

There are many strengths to this study. First, it included data covering a period of 17 months from March 2021 up until the summer months of 2022, covering the time from the initial limited vaccine rollout to a period where nearly everyone in the US had access to vaccines. We were therefore able to capture whether COVID-19 vaccine hesitancy has changed over time and examine potential variations across smoking status across different phases of the pandemic. Second, because of the variants that resulted in case surges at different times, we could qualitatively examine associations between rises and falls in COVID-19 cases and how they might have impacted attitudes about vaccination. Third, we collected open-ended responses to understand why individuals may be hesitant.

The main limitation of this study is that smoking status was obtained from the 2019 OMAS. Thus, some participants could have changed their smoking status by the time they were selected for the OCS. A second limitation is that we could not account for smoking intensity, as the 2019 OMAS only gathered information about smoking status.

PUBLIC HEALTH IMPLICATIONS

At certain periods during the COVID-19 pandemic, Ohioans who smoked appeared to be more hesitant to receive the COVID-19 vaccine compared to those who never smoked. Across all waves, the prevalence of vaccine hesitancy was higher among adults who smoked; and across 3 of the 6 initial waves (March 8, 2021 – November 28, 2021) adults who smoked were significantly more hesitant compared to their nonsmoker counterparts. Although these results suggest that vaccine hesitancy could have attenuated over time, increases in hesitancy in the summer months of 2022 indicate a need to further understand and characterize smokers' attitudes toward the vaccine. These results may help public health officials and health care providers in Ohio to better educate adults who smoke so that they become less hesitant and more likely to receive a COVID-19 vaccine. These findings also have implications for other vaccines designed to prevent lung infections, such as the influenza and pneumococcal vaccines. Future research should examine the extent to which people who smoke are hesitant to receive these immunizations. Tailored interventions may be needed to promote uptake of these vaccines.

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PB conducted the literature review and wrote the initial draft of the paper.
AT conducted all analyses and edited the paper.
MN, LT, TS, NF were all involved in the design and collection of OCS data.
AF was involved in all aspects of the paper, collection of OCS data, and analysis of qualitative data. AF also engaged in heavy editing of the paper prior to submission.

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Erratum:
1/19/2024: Corrected affiliation for Timothy R. Sahr.