COVID-19 Vaccination Uptake and Hesitancy Among Current Tobacco Users

Nicolle M Krebs[1] , Gail D'Souza[1], Candace Bordner[1,2],
Sophia I Allen[1] , Andrea L Hobkirk[1,2] , Jonathan Foulds[1,2] and
Jessica M Yingst[1]

[1]Department of Public Health Sciences, Penn State University College of Medicine, Hershey, PA, USA.
[2]Department of Psychiatry and Behavioral Health, Penn State University College of Medicine, Hershey, PA, USA.

ABSTRACT

Novel mRNA vaccines have been developed and were first distributed to high-risk individuals (including smokers) in the United States starting in December 2020 to combat the coronavirus (COVID-19) pandemic. Over one-half of the U.S. adult population has received at least 1 dose of a COVID-19 vaccine, but many others have reported hesitation about becoming vaccinated. We examined COVID-19 vaccine uptake and hesitancy from a convenience sample of Pennsylvanian adult smokers in April 2021, approximately 3 months after tobacco users were eligible to receive vaccination in the state. Participants (n = 231) were 23.4% male, 90.5% white, and had a mean age of 48.1 (SD = 11.9) years. All participants were current tobacco users, with the majority reporting current cigarette smoking (90.9%) with an average of 16 (SD = 8.1) cigarettes smoked per day. Nearly 60% (n = 137) reported receiving at least 1 dose of the vaccine and of those who did not (n = 94), 84% (n = 79) said they were somewhat or very unlikely to get a vaccine. Those who were unvaccinated were more likely to not consume news about COVID-19 (chi-square P-value < .01) and less likely to believe government news sources as reliable information for COVID-19 (chi-square P-value < .01). Qualitative responses among those who were vaccine hesitant expressed concerns about the lack of research on the vaccine, distrust of the safety of the vaccine, and fears about side effects. Understanding vaccine hesitancy among tobacco users can help develop targeted communication strategies and directly address concerns to promote vaccination among this population who may be at an increased risk of severe complications from COVID-19.

KEYWORDS: COVID-19, vaccination, hesitancy, tobacco, smoking

Introduction

The coronavirus disease 2019 (COVID-19) created a global pandemic that has caused 3.7 million deaths worldwide, and nearly 600 000 deaths in the United States (U.S.) as of June 2021.[1] Novel mRNA vaccines were developed and first distributed to the U.S. population in December 2020. In the U.S., the Advisory Committee on Immunization Practices (ACIP) provided guidance to federal and state agencies, including the Centers for Disease Control and Prevention (CDC), on the allocation of vaccine doses due to the expected initial high demand and low supply of available vaccines. The ACIP recommended individuals 16–64 years old with high-risk medical conditions, which included smoking, should receive a vaccine during the initial allocation phase because of their increased risk for severe COVID-19–associated illness. Since then, vaccine eligibility has expanded to everyone in the U.S. aged 12 years and older, and approximately 57% of the U.S. adult population has received at least one dose of the COVID-19 vaccine (as of May 22, 2021).[2]

COVID-19 vaccines showed 94-95% effectiveness in placebo-controlled clinical trials[3,4] and interim data on real-world effectiveness has held steady at 90%.[5] The degree to which lives are saved and disease is prevented is directly tied with the number of vaccines administered to the population.[6] Individuals who have not yet received the vaccine may be more vaccine hesitant. Common reported reasons for not becoming vaccinated are lack of trust in government and pharmaceutical companies, potential side effects, and concern with the speed of vaccine development without full evaluation.[7,8] Generally, individuals who live in rural regions, have lower income or education, and racial and ethnic minorities are less willing to receive the vaccine.[9-13]

Consistent evidence from numerous countries finds that smokers are less likely than non-smokers to be infected by COVID-19,[14-17] but if infected, smokers have had higher disease severity.[18,19] Typically, more severe cases result in higher usage of healthcare resources, including longer hospital stays, which makes it important to understand vaccination perceptions

and hesitancy among tobacco users to help avert overloading the healthcare system. Studies from the United Kingdom[20] and Hong Kong[21] found graded associations between smoking status (never, former, current) and vaccine hesitancy, even after controlling for covariates. Other studies focused on the general population found higher vaccination hesitancy by current reported smoking status,[22,23] except one which found the opposite relationship.[24] Another study[25] on vaccine hesitancy collected past 30-day use of cigarettes and e-cigarettes among survey respondents but found no association between use and vaccine hesitancy. Among other vaccines, such as the influenza vaccine, smokers have lower rates of vaccine administration.[26-28]

Our study aims to describe COVID-19 vaccine uptake among current tobacco users, and describe the factors related to vaccine hesitancy. Unique to this study, we will evaluate reasons for vaccine hesitancy using qualitative responses. Currently, there is limited understanding of vaccine perceptions and uptake among tobacco users. To our knowledge, only one U.S. study on COVID-19 vaccine hesitancy has collected tobacco use data among respondents,[25] and within that study, use was captured as a dichotomous variable and frequency of use was not reported. In an effort to target vaccine-related communications among tobacco users, there is a need for more thorough investigations into why certain population subgroups may be more vaccine hesitant than others.

Methods

Study population

Participants were members of a tobacco user research registry who agreed to be contacted for future tobacco-related research at the Penn State College of Medicine in Hershey, Pennsylvania. This research was approved by the Penn State College of Medicine Institutional Review Board (Protocol #- STUDY14949). Participants were entered into the registry from August 2015 to April 2021. Email invitations with a unique survey link were sent to the 3867 email addresses, of which 3509 were valid, on April 21, 2021. This was approximately 3 months after tobacco users were eligible to receive vaccination in the state of Pennsylvania. For context, current tobacco users in Pennsylvania were eligible to receive a COVID-19 vaccination as of January 19, 2021 under Phase 1A per the recommendations provided by the CDC.[29] Beginning April 13, 2021, all Pennsylvania residents became eligible for vaccination.

Quantitative data collection

Research Electronic Data Capture (REDCap) hosted at Penn State Health Milton S. Hershey Medical Center and Penn State College of Medicine was used to send the survey invitations and collect the data. REDCap is a secure, web-based application designed to support data capture for research studies.[30] Two subsequent reminder emails were sent weekly to those who did not respond to the initial invitation. Upon clicking the unique survey link, participants were provided with a summary of the research. Participants provided implied consent by clicking to continue with the survey. Participants were asked a series of questions about their demographic information, including their age, sex, race, ethnicity, and education level. In addition, participants were asked to report on their current use of tobacco. First, participants were asked, "Do you currently use cigarettes, electronic cigarettes/vape pens, cigars, pipes, snus/snuff/dip, chew, hookah/waterpipe, or dissolvables?" (yes/no). Those who responded "yes" were asked to indicate the products used, the times per day used, and the total time used (in years). Participants who reported current use of both cigarettes and e-cigarettes were considered dual users.

Participants were also asked questions about their experiences with COVID-19 including any symptoms they experienced. Participants were asked, "Starting in March 2020, we all became aware of an infectious virus (Coronavirus or COVID-19) that has spread across the country and the world. At any point in time from February 2020 onwards, did you experience symptoms that made you believe you may have contracted the virus?" (yes/no). Participants were also asked, "Have you ever tried to get tested for COVID-19?" (yes/no). Those who reported "yes" were asked to report the results of the test (test is pending, negative, positive). Participants were also asked about their perceptions of risk for catching COVID-19 and experiencing serious complications with the following 2 questions, "How do you perceive your risk of catching COVID-19 compared with those who do not use tobacco or nicotine products?" and "If you were to catch COVID-19, how do you perceive your risk of suffering serious complications compared with those who do not use tobacco or nicotine products (Much less likely, less likely, the same, more likely, much more likely)?". To gauge the overall impact of COVID-19 on participants we asked, "Overall, how much distress have you experienced related to COVID-19?" where participants answered on a scale from 1 (no distress) to 10 (extreme distress). Lastly, participants were asked which sources provide the most reliable information about COVID-19, and choices were grouped into government sources (federal government officials, The President, state or local governments), print/radio/television sources, online sources (online news sites, social media), personal networks (friends, family, work, church), or participants could state they do not consume news about COVID-19.

Finally, participants were asked about their vaccination status with the question, "Have you received at least 1 dose of a COVID-19 vaccine?" (yes/no). Those who reported "yes" were asked if they have received both doses, if the Pfizer or Moderna vaccine was received. Those who reported they have not received at least one dose of the vaccine were asked, "How likely are you to get vaccinated for coronavirus once a vaccination is available to you?" (Very unlikely, somewhat unlikely, somewhat likely, very likely, unsure).

Qualitative data collection

Participants were asked several open-ended questions in the survey to provide opportunity to elaborate on the quantitative

questions. In regard to vaccine hesitancy, participants who did not receive at least 1 dose of a COVID-19 vaccine were asked to, "Please elaborate on your answer of your likelihood of getting the vaccination." The purpose of this follow-up question was to gain a deeper understanding of the drivers behind vaccine hesitancy among the survey respondents and to add depth to our findings from the quantitative questions.

Quantitative data analysis

Participants who were current tobacco users and answered the question pertaining to whether they were vaccinated were included in the analysis. In addition, all participants included in the analysis were at least 21 years of age and could read and write in English. Means and frequencies were used to describe the sample. T-tests and chi-square analyses were used to determine differences in demographic and COVID-19–related variables between those vaccinated (at least one dose) and those who were not vaccinated at the time of the survey. A logistic regression model (n = 141) was used to predict vaccination status (outcome = unvaccinated). Participants were excluded from the model if they had any missing data within the variables included in the model. Independent variables included in the model were age, sex (male/female), race (white/not white), ethnicity (Hispanic/not-Hispanic), education (college degree or greater/less than college degree), cigarette user (yes/no), e-cigarette user (yes/no), other tobacco user (yes/no), COVID-19 symptoms (yes/no), ever tested for COVID-19 (yes/no), ever tested positive for COVID-19 (yes/no), recommended to quit smoking (yes/no), risk of catching COVID-19 (greater/same or less), and risk of suffering serious complications from COVID-19 (greater/same or less). A *P*-value of less than .05 was considered statistically significant.

Qualitative data analysis

All open-ended responses were imported into NVIVO 10 software (QSR International, Burlington, MA, USA) for coding and analysis. Researchers generated a codebook using inductive coding methods. Researchers (JY and GD) independently reviewed the responses and generated codes to cover the data. Then, researchers met to discuss the independently developed codes and generated the final codebook. Researchers then coded the data, while meeting regularly to revise codes as needed. Inter-coder reliability was calculated and agreement kappa > .80 was achieved. Participant responses which addressed more than one theme were included under both themes.

Results

Participants (n = 231) were 23.4% male, 90.5% white, a mean age of 48.1 years, and 20.2% earned a college degree or greater. All participants were current tobacco users, with the majority reporting current cigarette smoking (90.9%). More than half of participants reported ever being tested for COVID-19 (60.0%;

n = 138/230), with 15.3% (21/138) reporting ever testing positive (Table 1).

Over half of participants reported receiving at least one dose of the COVID-19 vaccination (59.3%; 137/231) and 44.2% (102/231) reported full-vaccination (ie, received 2 doses of Pfizer/Moderna, or 1 dose of Johnson and Johnson). Those who reported receiving at least one dose of the vaccine were older, smoked cigarettes a greater number of years, were more likely to have a college degree, and were more likely to report greater risk of catching COVID-19 and suffering serious complications, compared to those who were not vaccinated at the time of the survey (Table 1). The logistic regression model revealed that among all tobacco users, younger age, Hispanic ethnicity, higher distress over COVID-19, consuming no news about COVID-19, not endorsing information from the government about COVID-19 as reliable, and not ever being tested for COVID-19 were significant predictors of being unvaccinated (Table 2). Experiencing symptoms of COVID-19 or testing positive for COVID-19 did not impact getting vaccinated.

Among the 40.7% (n = 94) who had not received at least one dose of the COVID-19 vaccination at the time of the survey, only 16% (n = 15) reported that they were somewhat or very likely to get a COVID-19 vaccination when available. The majority reported that they were unsure, or somewhat to very unlikely to get the vaccination (84%, n = 79).

Among those hesitant to get the vaccine (n = 79), 65 participants (82.2%) provided comments explaining their beliefs and attitudes about COVID-19 vaccination (Supplementary Table 1). Most commonly, participants expressed general concerns related to the amount of research and testing conducted on the vaccine. They said, *"I feel like there is not enough research to support getting this vaccine"* and *"I don't trust it due to the fact it was not tested long enough. It takes years to come up with a vaccine … it was released too fast…".* Many participants also expressed the belief that the vaccine was still in the experimental stages. Participants said, *"I will not get an experimental vaccination"* and *"I am not a lab rat".*

The perceived lack of research and belief that the vaccine is experimental led many participants to report lack of trust in the vaccine. One participant said, the *"vaccine was developed too quick. I don't trust it. No cure for cancer, common cold* etc. *A vaccine for COVID-19 developed in less than a year. No thanks".* Another said, *"honestly I do not trust the vaccine! I will wait and see all the actual data."* Some participants specifically expressed a lack of trust in the vaccine due to their beliefs about pharmaceutical companies. They said, *"I have no intention of getting the vaccine. I would prefer to take my chances with COVID than risk suffering permanent side effects from the vaccine, specially knowing that the pharmaceutical companies cannot be held responsible for any lasting side effects"* and *"I do not believe in vaccinations and I do not trust these big Pharma companies to have our best interest in mind."*

Others commented that the perceived lack of research and testing could result in unknown side effects. One participant

Table 1: Characteristics overall and by vaccination status.

	OVERALL	VACCINATED[a] (N = 137)	NOT VACCINATED (N = 94)	*P*-VALUE
Sociodemographic characteristics				
Mean age (SD)	48.1 (11.9)	50.5 (12.3)	44.6 (10.3)	**<.01**
% (n) male	23.4 (54)	21.2 (29)	26.6 (25)	.34
% (n) Hispanic or Latino (n = 229)	3.5 (8)	2.2 (3)	5.4 (5)	.20
% (n) white	90.5 (209)	92.7 (127)	87.2 (82)	.16
% (n) earned college degree (n = 228)	20.2 (46)	25.0 (34)	13.0 (12)	**.03**
Smoking characteristics				
% (n) cigarette smoker	90.9 (210)	92.0 (126)	89.4 (84)	.50
Mean cigarettes per day (SD) (n = 208)	16.0 (8.1)	15.8 (7.6)	16.1 (9.0)	.79
Mean years smoked (SD)	28.0 (12.7)	30.1 (13.0)	24.8 (11.7)	**<.01**
% (n) e-cigarette user	15.2 (35)	14.6 (20)	16.0 (15)	.78
Mean times per day (SD) (n = 33)	2.8 (2.1)	2.6 (2.5)	3.1 (1.6)	.44
Mean years vaped (SD)	2.4 (1.6)	2.4 (1.5)	2.4 (1.8)	1.0
% (n) other tobacco user	3.9 (9)	2.9 (4)	5.3 (5)	.35
% (n) dual user of cigarettes and e-cigs	8.2 (19)	8.8 (12)	7.5 (7)	.72
COVID-19 characteristics				
% (n) ever have symptoms of COVID-19	35.9 (83)	36.5 (50)	35.1 (33)	.83
% (n) ever tested for COVID-19	60.0 (138)	64.0 (87)	54.3 (51)	.14
% (n) ever tested positive for COVID-19	15.3 (21)	8.0 (11)	10.6 (10)	.50
% (n) perceive greater risk of catching COVID-19 (n = 155)	23.2 (36)	30.7 (27)	13.4 (9)	**.01**
% (n) perceive greater risk for serious complications from COVID-19 (n = 156)	59.6 (93)	70.5 (62)	45.6 (31)	**<.01**
Mean distress experienced related to COVID-19 (SD) (range 1–10) (n = 230)	5.5 (2.6)	5.6 (2.4)	5.4 (2.9)	.63
% (n) who endorsed news sources as most reliable for COVID-19 information (n = 217)				
Government sources	40.6 (88)	49.6 (66)	26.2 (22)	**<.01**
Print/radio/television sources	17.5 (38)	17.3 (23)	17.9 (15)	.92
Online sources	14.3 (31)	15.8 (21)	11.9 (10)	.43
Personal networks	3.7 (8)	4.8 (4)	3.0 (4)	.50
Does not consume news about COVID-19	24.0 (52)	14.3 (19)	39.3 (33)	**<.01**

[a]Reported receiving at least one dose of a COVID-19 vaccine.
Note: Variables with missing data have the total sample size in parentheses.

said, *"I just hear the side effects of the vaccine and that doesn't make me feel comfortable."* Another said *"I'm afraid of long term effects 10–20 years from now."* In addition, some feared unknown side effects because of health conditions or previous negative vaccine experiences. One participant said, *"Most serious reactions to the vaccine have been in patients with allergies to meds. I am allergic to 3 meds (two developed within the last 5 yrs) and had a documented reaction to a dose of the anthrax vaccine. I am not an anti-vaxer or a conspiracy theorist. But I am concerned about how my body may react given my individual circumstances."* Another said, *"I'm one of those people who tend to have negative vaccine reactions."*

Several participants also mentioned that they did not perceive benefits from getting the COVID-19 vaccine. Some comments were related to having a good immune system. One participant said, *"I do not see the necessity in it. Generally when I*

get sick it does not last long. My immune system is good." Others felt they did not need to get the vaccine because they had COVID-19. One participant said, *"I have strong antibodies due to recently having COVID".* Another participant did not find getting the vaccine to be beneficial because personal protective equipment (PPE) requirements had not changed. They said, *"I am not getting the vaccine because it doesn't matter, you are still supposed to wear a mask and avoid people so what would change."*

Less common comments related to the COVID-19 vaccine were related to general vaccine and shot hesitancy and logistic issues. Some participants were not planning to get the COVID-19 vaccination because they do not receive any vaccinations. One participant said, *"I don't vaccinate."* Another reported hesitancy due to fear of shots, simply stating, *"I don't like getting shot.s"* Finally, a few participants reported logistic issues as a

Table 2. Logistic regression model with predictors of being unvaccinated.

CHARACTERISTIC	ODDS RATIO (OR)	95% CONFIDENCE INTERVAL (CI)	BETA (β)	P-VALUE
Age (continuous)	.95	.92–.99	−.05	<.01
Hispanic ethnicity[a]	21.90	1.99–240.64	3.09	.01
COVID-19 distress (range 1–10)	1.21	1.01–1.45	.19	.04
COVID-19 news consumption[a]	.18	.06–.57	−1.69	<.01
Endorses COVID-19 news from government as reliable[a]	.25	.09–.66	−1.41	<.01
Has been tested for COVID-19[a]	.20	.08–.50	−1.60	<.01

[a]Variable coded as 1 = yes and 0 = no.

barrier to being vaccinated. One participant said, *"I have no car or money to get places."* None of the participants mentioned awareness that studies have found smokers to be less likely to be infected with COVID-19,[14-16] as a reason for not getting vaccinated.

Discussion

Vaccinations against COVID-19 provide hope for relaxing restrictions and more importantly, preventing further death and disease from the virus.[6,31] However, not everyone agrees with this public health approach, which has resulted in some of the population remaining unwilling to receive a vaccine. Our study provided a firsthand look at vaccine uptake and willingness among tobacco users in the U.S, a group at greater risk for COVID-19 disease severity if infected.[18,19,32] Within our study, nearly 60% reported receiving at least one dose of the COVID-19 vaccine which is on par with the national average in the U.S (57%; as of May 22, 2021).[2]

While current adult tobacco users were eligible for vaccination for more than 3 months at the time of survey, 40% had not received their first dose of the COVID-19 vaccine. Of those, the majority (84%) were either unwilling or undecided in getting the vaccine. Before the vaccine was available, a study sampled adults with a history of tobacco and/or marijuana use[25] where 51% said they were either unsure or would not receive a vaccine if it was available to them. In the United Kingdom, current smokers reported significantly greater mistrust in the vaccine and vaccine manufactures and had greater concerns about unknown side effects compared to never or former smokers.[20] For vaccines that are perhaps less controversial (ie, pneumonia and influenza), lower vaccination rates in smokers have been reported[28] which may suggest an overall lower utilization of healthcare resources and healthy behavior choices among smokers.

These same concerns were found within our qualitative analysis of reasons for vaccine hesitancy. For example, many smokers reported vaccine hesitancy due to a fear of suffering from side effects. While this concern prevented many from receiving the vaccine, the reported serious adverse events after receiving the vaccine continue to be extremely rare. Severe

allergic reactions, for example, anaphylaxis have occurred in about 2–5 people per million vaccinated in the U.S.[33] On the other hand, post-COVID-19 patients have reported reduced physical and cognitive abilities after recovering from the virus, suggesting COVID-19 itself may have greater long-term effects on health than previously known.[34-36]

Based on the elevated risks of COVID-19 to smokers, the CDC recommended individuals who smoke to be included in the first tier to receive the vaccine.[37] Among our sample, receiving COVID-19 information from the government was in fact related to higher vaccine uptake. The elevated risk to smokers may not be fully understood by the lay public, and public health risk messaging specific for smokers may not be reaching this population, if it even exists at all. Comparing elevated COVID-19 risks between individuals who smoke and do not smoke may have more impact for smokers who are hesitant because of the increased personal context. As an example, those who are not fully vaccinated are 5 times more likely to be infected and 10 times more likely to be hospitalized or die from COVID-19.[38] This information could be tailored to state the differences in the likelihood of these outcomes between smokers vs non-smokers instead. Targeted messaging that includes personally relevant information may be particularly helpful in decreasing vaccine hesitancy.[39]

A report from the National Academies of Science, Engineering and Medicine[39] emphasizes that in order to improve confidence in the vaccine it is necessary to address specific concerns within the population using easily understandable information, supported by evidence, and delivered by trusted sources. There is potential to overcome COVID-19 vaccine hesitancy by using transparent messaging on both the calculated risks and benefits of receiving the vaccine, so the public can make an informed decision for themselves. In our study, those who perceived greater health risks from COVID-19 were more likely to get vaccinated, indicating that knowledge about the true dangers of COVID-19 could possibly impact vaccination rates. Additionally, we found that unvaccinated smokers were less likely to seek COVID-19 information, and particularly not from government sources, so vaccination messaging from CDC or FDA (Food and Drug Administration) may not be as

effective. It may be more productive for healthcare providers, as trusted messengers, to discuss and address vaccine concerns with their patients who smoke. Discussing the risks of COVID-19 with smokers may lead to further discussion on the health benefits from smoking cessation in general.

During the pandemic, scientists speculated on a potential protective effect of nicotine/smoking from COVID-19 infection due to initial low incidence rates among smokers. While definitive evidence for causality has not been established, media outlets have circulated this information on various internet sites, in addition to social media, which may have been associated with increases in tobacco use during the pandemic according to one survey.[40] It could be hypothesized that such information may encourage smokers not to receive the vaccine if they believed they were protected otherwise. However, exposure to these claims was not mentioned as a reason for not getting vaccinated among the tobacco users in our sample. General misinformation about COVID-19 and the vaccine has led to confusion and outright rejection of public health safety measures, and recently has been recognized as a serious threat to public health by the U.S. Surgeon General.[41] Addressing misinformation is one of the key strategies to encounter vaccine hesitancy.[39]

Smokers in this study raised concerns about the COVID-19 vaccine such as, "unknown long-term side effects" and "the vaccine has not been studied long enough." These concerns among communities should be directly addressed by public health officials as they stem from real emotions, such as fear and worry. Messages that acknowledge their concerns combined with facts about the effectiveness of the vaccine could be a novel approach to reaching the unvaccinated. It may be important in some communities to have positive, constructive dialogues surrounding vaccines and individual rights vs collectivism. An international study that assessed the barriers to COVID-19 vaccine uptake found individuals with more collective and altruistic beliefs had stronger vaccination intentions.[42] It is important to be aware of these external factors that are beyond medical and scientific-based facts that some people consider when weighing their decision to become vaccinated.

Limitations for this study are present. For example, this is a non-representative sample of tobacco users and users were only surveyed at one point in time. However, we assessed vaccine hesitancy during vaccine rollout when people were making actual instead of hypothetical choices to vaccinate which allowed us to capture vaccine uptake among our sample of smokers. Additionally, we collected more nuanced data on tobacco use behaviors and tobacco use history, such as number of years used and daily use frequency, compared to previous reports which allowed more distinct characterization of vaccination outcomes. There is potential for response bias due to the low response rate within our sample, most likely caused by the lack of incentive for completing the survey. Based on limited data we have on non-respondents, we found non-respondents were slightly younger (mean = 41.4; SD = 19.1) and included more men (male = 38.2%)

compared to the participants who completed the survey. In addition, because we only recruited tobacco users, we were not able to compare outcomes between tobacco users and non-users. The data generated from the open-ended responses provide an initial exploration on reasons for vaccine hesitancy among smokers. More in-depth qualitative data collection in the form of focus groups or individual interviews should be conducted to thoroughly assess reasons for hesitancy that are specific to this population. Last, it is important to note that because of the cross-sectional nature of the study, causality cannot be determined or inferred from our data.

Fortunately, vaccine hesitancy is not necessarily equivalent to outright refusal to be vaccinated, and addressing concerns among the population could increase vaccination rates. This study provides important insight regarding whether tobacco users are hesitant to get the COVID-19 vaccine, the factors related to hesitancy, and the reasons for hesitancy. This data can help public health officials by providing a better understanding of vaccine hesitancy among tobacco users that can be used to develop targeted education and communication strategies to promote vaccination.

ORCID iDs

Sophia I Allen ⬛ https://orcid.org/0000-0002-1809-3749
Jessica M Yingst⬛ https://orcid.org/0000-0003-3028-668X
Nicolle M Krebs ⬛ https://orcid.org/0000-0002-5824-4572
Andrea L Hobkirk ⬛ https://orcid.org/0000-0002-3020-3963

REFERENCES

1. Johns Hopkins University. *Coronavirus Resource Center*. https://coronavirus.jhu.edu/. https://coronavirus.jhu.edu/. Accessed June 20, 2021.
2. Diesel J, Sterrett N, Dasgupta S, et al. COVID-19 vaccination coverage among adults - United States, December 14, 2020-May 22, 2021. *MMWR Morb Mortal Wkly Rep*. 2021;70(25):922-927. doi:10.15585/mmwr.mm7025e1.
3. Polack FP, Thomas SJ, Kitchin N, et al. Safety and efficacy of the BNT162b2 mRNA covid-19 vaccine. *N Engl J Med*. 2020;383(27):2603-2615. doi:10.1056/NEJMoa2034577.
4. Baden LR, El Sahly HM, Essink B, et al. Efficacy and safety of the mRNA-1273 SARS-CoV-2 vaccine. *N Engl J Med*. 2021;384(5):403-416. doi:10.1056/NEJMoa2035389.
5. Thompson MG, Burgess JL, Naleway AL, et al. Interim estimates of vaccine effectiveness of BNT162b2 and mRNA-1273 COVID-19 vaccines in preventing SARS-CoV-2 infection among health care personnel, first responders, and other essential and frontline workers - eight U.S. locations, December 2020-March 2021. *MMWR Morb Mortal Wkly Rep*. 2021;70(13):495-500. doi:10.15585/mmwr.mm7013e3.
6. Bartsch SM, Wedlock PT, O'Shea KJ, et al. Lives and costs saved by expanding and expediting coronavirus disease 2019 vaccination. *J Infect Dis*. 2021;224:938-948. doi:10.1093/infdis/jiab233.
7. Dror AA, Eisenbach N, Taiber S, et al. Vaccine hesitancy: The next challenge in the fight against COVID-19. *Eur J Epidemiol*. 2020;35(8):775-779. doi:10.1007/s10654-020-00671-y.
8. Schernhammer E, Weitzer J, Laubichler MD, et al. Correlates of COVID-19 vaccine hesitancy in Austria: trust and the government. *J Publ Health (Oxf)*. 2021. 10.1093/pubmed/fdab122..
9. Kelly BJ, Southwell BG, McCormack LA, et al. Predictors of willingness to get a COVID-19 vaccine in the U.S. *BMC Infectious Diseases*. 2021;21(1):338. doi:10.1186/s12879-021-06023-9.
10. Gatwood J, McKnight M, Fiscus M, Hohmeier KC, Chisholm-Burns M. Factors influencing likelihood of COVID-19 vaccination: A survey of Tennessee adults. *Am J Health Syst Pharm : AJHP : official journal of the American Society of Health-System Pharmacists*. 2021;78(10):879-889. doi:10.1093/ajhp/zxab099.

11. Reiter PL, Pennell ML, Katz ML. Acceptability of a COVID-19 vaccine among adults in the United States: How many people would get vaccinated?. *Vaccine*. 2020; 38(42):6500-6507. DOI: 10.1016/j.vaccine.2020.08.043.

12. Barry V, Dasgupta S, Weller DL, et al. Patterns in COVID-19 vaccination coverage, by social vulnerability and urbanicity - United States, December 14, 2020-May 1, 2021. *MMWR Morb Mortal Wkly Rep*. 2021;70(22):818-824. doi:10.15585/mmwr.mm7022e1.

13. Murthy BP, Sterrett N, Weller D, et al. Disparities in COVID-19 vaccination coverage between urban and rural counties - United States, December 14, 2020-April 10, 2021. *MMWR Morb Mortal Wkly Rep*. 2021;70(20):759-764. doi:10.15585/mmwr.mm7020e3.

14. Simons D, Shahab L, Brown J, Perski O. The association of smoking status with SARS-CoV-2 infection, hospitalization and mortality from COVID-19: A living rapid evidence review with Bayesian meta-analyses (version 7). *Addiction*. 2021; 116(6):1319-1368. doi:10.1111/add.15276.

15. Farsalinos K, Barbouni A, Poulas K, Polosa R, Caponnetto P, Niaura R. Current smoking, former smoking, and adverse outcome among hospitalized COVID-19 patients: A systematic review and meta-analysis. *Ther Adv Chronic Dis*. 2020;11: 204062232093576. doi:10.1177/2040622320935765.

16. Paleiron N, Mayet A, Marbac V, et al. Impact of tobacco smoking on the risk of COVID-19: A large scale retrospective cohort study. *Nicotine Tob Res*. 2021;23: 1398-1404. doi:10.1093/ntr/ntab004.

17. Jose T, Croghan IT, Hays JT, Schroeder DR, Warner DO. Electronic cigarette use is not associated with COVID-19 diagnosis. *J Primary Care Com Health*. 2021;12: 215013272110243. doi:10.1177/21501327211024391.

18. Alqahtani JS, Oyelade T, Aldhahir AM, et al. Prevalence, severity and mortality associated with COPD and smoking in patients with COVID-19: A rapid systematic review and meta-analysis. *PLoS One*. 2020;15(5):e0233147. doi:10.1371/journal.pone.0233147.

19. Zhang H, Ma S, Han T, et al. Association of smoking history with severe and critical outcomes in COVID-19 patients: A systemic review and meta-analysis. *European journal of integrative medicine*. 2021;43:101313. doi:10.1016/j.eujim.2021.101313.

20. Jackson SE, Paul E, Brown J, Steptoe A, Fancourt D. Negative vaccine attitudes and intentions to vaccinate against Covid-19 in relation to smoking status: A population survey of UK adults. *Nicotine Tob Res*. 2021;23:1623-1628. doi:10.1093/ntr/ntab039.

21. Luk TT, Zhao S, Wu Y, Wong JY, Wang MP, Lam TH. Prevalence and determinants of SARS-CoV-2 vaccine hesitancy in Hong Kong: A population-based survey. *Vaccine*. 2021;39(27):3602-3607. doi:10.1016/j.vaccine.2021.05.036.

22. Alqudeimat Y, Alenezi D, AlHajri B, et al. Acceptance of a COVID-19 vaccine and its related determinants among the general adult population in Kuwait. *Med Princ Pract*. 2021;30(3):262-271. doi:10.1159/000514636.

23. Sethi S, Kumar A, Mandal A, et al. The UPTAKE study: A cross-sectional survey examining the insights and beliefs of the UK population on COVID-19 vaccine uptake and hesitancy. *BMJ Open*. 2021;11(6):e048856. doi:10.1136/bmjopen-2021-048856.

24. Alibrahim J, Awad A. COVID-19 vaccine hesitancy among the public in Kuwait: A cross-sectional Survey. *Int J Environ Res Publ Health*. 2021;18(16):8836.

25. Yang Y, Dobalian A, Ward KD. COVID-19 vaccine hesitancy and its determinants among adults with a history of tobacco or Marijuana use. *J Community Health*. 2021; 46:1090-1098. doi:10.1007/s10900-021-00993-2.

26. Andrew MK, McNeil S, Merry H, Rockwood K. Rates of influenza vaccination in older adults and factors associated with vaccine use: a secondary analysis of the Canadian Study of Health and Aging. *BMC Public Health*. 2004;4:36. doi:10.1186/1471-2458-4-36.

27. Der-Martirosian C, Heslin KC, Mitchell MN, Chu K, Tran K, Dobalian A. Comparison of the use of H1N1 and seasonal influenza vaccinations between

28. Pearson WS, Dube SR, Ford ES, Mokdad AH. Influenza and pneumococcal vaccination rates among smokers: Data from the 2006 behavioral risk factor surveillance system. *Prevent Med*. 2009;48(2):180-183. doi:10.1016/j.ypmed.2008.11.001.

29. Pennsylvania Department of Health. *COVID-19 Vaccine Distribution*. https://www.health.pa.gov/topics/disease/coronavirus/Vaccine/Pages/Distribution.aspx. Accessed 8 July, 2021.

30. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inf*. 2009; 42(2):377-381. doi:10.1016/j.jbi.2008.08.010.

31. Usherwood T, LaJoie Z, Srivastava V. A model and predictions for COVID-19 considering population behavior and vaccination. *Sci Rep*. 2021;11(1):12051. doi:10.1038/s41598-021-91514-7.

32. DuPre NC, Karimi S, Zhang CH, et al. County-level demographic, social, economic, and lifestyle correlates of COVID-19 infection and death trajectories during the first wave of the pandemic in the United States. *Sci Total Environ*. 2021;786: 147495. doi:10.1016/j.scitotenv.2021.147495.

33. Centers for Disease Control and Prevention. *Selected Adverse Events Reported after COVID-19 Vaccination*. https://www.cdc.gov/coronavirus/2019-ncov/vaccines/safety/adverse-events.html. https://www.cdc.gov/coronavirus/2019-ncov/vaccines/safety/adverse-events.html. Accessed 8 July, 2021.

34. Rogers-Brown JS, Wanga V, Okoro C, et al. Outcomes among patients referred to outpatient rehabilitation clinics after COVID-19 diagnosis - United States, January 2020-March 2021. *MMWR Morb Mortal Wkly Rep*. 2021;70(27). doi:10.15585/mmwr.mm7027a2.

35. Taquet M, Geddes JR, Husain M, Luciano S, Harrison PJ. 6-month neurological and psychiatric outcomes in 236379 survivors of COVID-19: A retrospective cohort study using electronic health records. *Lancet Psychiatr*. 2021;8(5):416-427. doi:10.1016/S2215-0366(21)00084-5.

36. Hernandez-Romieu AC, Leung S, Mbanya A, et al. Health care utilization and clinical characteristics of nonhospitalized adults in an integrated health care system 28-180 days after COVID-19 diagnosis - Georgia, May 2020-March 2021. *MMWR Morb Mortal Wkly Rep*. 2021;70(17):644-650. doi:10.15585/mmwr.mm7017e3.

37. Dooling K, Marin M, Wallace M, et al. The advisory committee on immunization practices' updated interim recommendation for allocation of COVID-19 vaccine - United States, December 2020. *MMWR Morb Mortal Wkly Rep*. 2021;69(5152): 1657-1660. doi:10.15585/mmwr.mm695152e2.

38. Scobie HM, Johnson AG, Suthar AB, et al. Monitoring incidence of COVID-19 cases, hospitalizations, and deaths, by vaccination status - 13 U.S. Jurisdictions, April 4-July 17, 2021. *MMWR Morb Mortal Wkly Rep*. 2021;70(37):1284-1290. doi:10.15585/mmwr.mm7037e1.

39. National Academies of Sciences, Engineering, and Medicine. *Communication Strategies for Building Confidence in COVID-19 Vaccines: Addressing Variants and Childhood Vaccinations*. Washington, DC: The National Academies Press; 2021:23.

40. Luk TT, Zhao S, Weng X, et al. Exposure to health misinformation about COVID-19 and increased tobacco and alcohol use: a population-based survey in Hong Kong. *Tobac Control*. 2020;30:696-699. doi:10.1136/tobaccocontrol-2020-055960.

41. Office of the Surgeon General. Publications and reports of the surgeon general. *Confronting Health Misinformation: The US Surgeon General's Advisory on Building a Healthy Information Environment*. Washington, DC: US Department of Health and Human Services; 2021.

42. Burke PF, Masters D, Massey G. Enablers and barriers to COVID-19 vaccine uptake: An international study of perceptions and intentions. *Vaccine*. 2021;39(36): 5116-5128. DOI: 10.1016/j.vaccine.2021.07.056.