Distribution Agreement

In presenting this thesis or dissertation as a partial fulfillment of the requirements for an advanced degree from Emory University, I hereby grant to Emory University and its agents the non-exclusive license to archive, make accessible, and display my thesis or dissertation in whole or in part in all forms of media, now or hereafter known, including display on the world wide web. I understand that I may select some access restrictions as part of the online submission of this thesis or dissertation. I retain all ownership rights to the copyright of the thesis or dissertation. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation.

Signature:

5/3/2021

Kushagra Vashist Date

A National Investigation of Health Equity Considerations in COVID-19 Vaccination in the United States

By

Kushagra Vashist

Master of Public Health

Global Epidemiology

_____

Shivani A. Patel, PhD, MPH

Committee Chair

_____

Choi, Daesung, PhD

Committee Member

A National Investigation of Health Equity Considerations in COVID-19 Vaccination in the United States

By

Kushagra Vashist

City College of the City University of New York

2019

Thesis Committee Chair: Shivani A. Patel, PhD, MPH

An abstract of

A Thesis Submitted to the Faculty of the

Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of

Master of Public Health in Global Epidemiology

2021

Abstract

A National Investigation of Health Equity Considerations in COVID-19 Vaccination in the United States

By Kushagra Vashist

Background: After a half-million American deaths due to COVID-19, three SARS-COV-2 vaccines have been approved for emergency use. To reach herd immunity and control the spread of infection, an overwhelming majority of the population needs to be vaccinated. However, socio-demographic characteristics such as being person of color, having low income, and less educational attainment are expected to be adversely affected by COVID-19 infection and have lower vaccine uptake.

Methods: Using the 2018 National Health Interview Survey, we first described the distribution of non-institutionalized populations prioritized for COVID-19 by race and ethnicity, age, sex and region as per the Advisory Committee for Immunization Practices framework. Secondly, we identified socio-demographic groups that may be at risk for lower uptake of adult vaccinations by examining the differences in likelihood of getting flu vaccine by commonly identified priority groups for the remainder of the roll-out.

Results: We found that approximately 85% of US adults fall into Phase 1 and 15% fall into Phase 2 of the vaccine priority schedule. Phase 1 had a similar demographic composition relative to the US population. Phase 2 had greater share of men, younger adults and Hispanics. When examining prior flu vaccine receipt among COVID-19 vaccine priority groups, we found that the relative odds of receiving flu vaccine were significantly lower in medically vulnerable adults (aOR=0.43, 95% CI= 0.37, 0.48), essential workers (aOR=0.28, 95% CI= 0.23, 0.34), and the general population (aOR=0.32, 95% CI= 0.28, 0.37) compared to healthcare workers in the fully adjusted model. Factors associated with lower uptake included being young, male, of Black race, a current smoker, having no health insurance, less education, income lower than $100,000, and not researching health related information on the internet.

Conclusion: Our study highlights demographic groups at risk for lower COVID-19 vaccine uptake to guide the development of tailored strategies to increase equitable vaccine coverage. The medically vulnerable, non-healthcare essential workers, and general population have been less likely to get adult vaccines compared to healthcare workers. Being Black, young, male, less educated, earning less than $100,000, and having no health insurance were all associated with lower flu vaccine uptake.

A National Investigation of Health Equity Considerations in COVID-19 Vaccination in the United States

By

Kushagra Vashist

City College of the City University of New York

2019

Thesis Committee Chair: Shivani A. Patel, PhD, MPH

A Thesis Submitted to the Faculty of the

Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of

Master of Public Health in Global Epidemiology

2021

Table of Contents

Introduction

After a year of unprecedented social distancing and a half-million American deaths due to COVID-19, three SARS-COV-2 vaccines have been approved for emergency use since December 2020. Earliest prioritization for vaccine allocation was based on the goal of protecting Americans who are employed in high-exposure occupations needed for public wellbeing and protecting Americans who are most vulnerable to severe outcomes such as hospitalization and death.[1] The ultimate goal of vaccination, however, is to reduce circulation of the virus to achieve herd immunity, which is essential for the resumption of normalcy.[2] This will require vaccinating a critical mass of individuals—estimated at over 80% of the US population.

Due to vaccine demand exceeding supply in the initial months, the Advisory Committee for Immunization Practices (ACIP) formalized a framework for vaccine dissemination to priority groups[1]. The framework recommended that healthcare professionals and residents of long term facilities to be given vaccination first (Phase 1a). In December 2020, ACIP framework recommended that vaccines in Phase 1b should be given to individuals aged 75 and older and those working in non-healthcare essential occupations, and in Phase 1c, persons aged 65–74 years, persons aged 16–64 years with high-risk medical conditions, and essential workers not recommended for vaccination in Phase 1b.[1]

Long standing systemic health and social inequities such as discrimination, low healthcare access and utilization, high-risk occupations to COVID-19, low income and education, and deprived housing have put people of color, especially Black Americans at a higher risk of infection, hospitalization and death.[3,4] Yet, reports suggest that public vaccination sites are less likely to be in communities of color in the South[5] and that racial/ethnic minorities

are overall more hesitant than whites to take the vaccine.[6] This hesitancy may emerge from misinformation, historical or current medical mistreatment, corresponding mistrust and ongoing experiences of discrimination.[7] Therefore, understanding the demographic composition of the US population prioritized for vaccination is critical to track equity in vaccine coverage and to better tailor health communication strategies.

While racial and ethnic differences contribute to differential vaccination, level of education is a critical factor in vaccine uptake as well.[8] Individuals with less education are more likely to work and live in conditions that increase their likelihood of infection and death.[8] Estimates suggest that individuals with a college degree are on an average 43% more likely to get vaccinated compared to those without one.[8] Furthermore, adults with low income and living in rural areas may also be more hesitant to get vaccinated.[7]

The aims of this thesis were to first generate national benchmarks to track the demographic coverage of COVID-19 vaccination among priority groups, and second to a) identify socio-demographic groups that have historically had lower uptake of adult vaccinations and b) inform expectations around COVID-19 vaccination for the remainder of the roll-out by examining the differences and likelihood of getting flu vaccine by commonly identified priority groups. To address these aims, we analyzed nationally representative data collected through the US National Health Interview Survey, 2018. The findings of this research may be used to inform and address approaches to achieve equitable distribution of the COVID-19 vaccine across the United States.

To address the aims of the study, we first identified the distribution of non-institutionalized priority population for COVID-19 by race/ethnicity, age, sex, and regional

distribution according to the Advisory Committee for Immunization Practices (ACIP).[1] Due to states apply discretion to deviate from the ACIP framework in determining eligibility for vaccination, we categorized US adults into four broad groups that have commonly been used to determine eligibility thus far: healthcare workers, the medically vulnerable, essential occupations outside of healthcare, and the remaining general population. We hypothesized that the US experience with the seasonal influenza vaccine may provide useful insight on expected behaviors regarding COVID-19 vaccination.

Literature review

Vaccines are important tools in reducing the incidence, prevalence, morbidity, and mortality of many vaccine-preventable diseases.[11] In addition to preventing disease, vaccines play a large role in the prevention and reduction of societal burden through indirect costs of infectious disease, such as absenteeism from work and productivity losses.[12] Yet, even when vaccines are available, coverage is often far from optimal. There are several contributing factors to under-coverage of vaccinations in the population, including structural barriers such as affordability, accessibility, and operational or systemic barriers, and attitudinal barriers like vaccination being deemed low priority, lack of knowledge, and fear or opposition to vaccines.[11]

Both flu and COVID-19 vaccines target adult populations and require similar infrastructure for distribution and vaccination. Recent studies have demonstrated that demographic patterns of attitudes and behaviors regarding uptake of the seasonal influenza vaccine may be similar to attitudes and behaviors for the COVID-19 vaccine. For instance, early data show a correlation between having received the annual flu vaccine and COVID-19 vaccine acceptability among Black Americans and older adults.[9] Furthermore, flu vaccine uptake was significantly associated with higher acceptability COVID-19 vaccination in a national study.[10] Therefore, this literature review summarizes the available evidence regarding vaccinations broadly in adult populations, and specifically, what is known about uptake of the seasonal flu vaccine.

Knowledge and attitude related factors have been documented as barriers to vaccine uptake in adult populations. Common adult vaccines preventing diseases such as influenza, tetanus/diphtheria/pertussis, human papillomavirus remain a low priority for many adults and physicians.[13] In comparison to schools, where it is mandatory for children to get vaccinated,

employers rarely have such a requirement, leading to less adult motivation to get vaccinated. A common reason cited for lack of vaccination included a perception that healthy individuals did not need to get vaccinated. [14] Lack of knowledge surrounding vaccination is perhaps one of the biggest mitigating factor in uptake.[13] Many adults are not aware of the numerous benefits of vaccination. [13] Many are of the opinion that vaccines are dangerous or do not work as advertised, and that keeping oneself hygienic is a better means of preventing infection.[15] Immunity derived from surviving a disease as opposed to vaccination has also been cited as a common reason for lack of vaccination.[16]

Beyond knowledge and attitude, several access-related barriers to vaccinations exist. Previous literature has emphasized the importance of ease of transportation in increasing uptake. Other factors such as language barriers as well as making vaccines readily accessible in nonmedical outlets and accommodating individuals with incomplete immunization records could be vital in increasing uptake as well.[15] In a digital day and age, access to internet is vital in making appointments and having services that can improve health.[17] However, this can serve as a barrier in less-educated and under resourced minority groups, as well as in older individuals.[17] Furthermore, uninsured individuals are less likely to receive vaccination.[18] Therefore, effective strategies in encouraging uninsured individuals is vital in increase vaccine uptake.

Uptake of vaccines for SARS-Cov-2 to protect against COVID-19 disease may be subject to some of the same structural and attitudinal barriers as other adult vaccines. Data suggest that many individuals, especially people of color and Blacks are at a higher risk of infection, hospitalization and death, in part due to social determinants of health such limited finances, as healthy food, education, health insurance and job flexibility [19]. In a recent study of mostly Non-Hispanic Black population, hesitancy to take COVID-19 vaccine was identified due to mistrust

in the health system, accelerated development of the vaccine, side effects and the perceived advancement of racial injustice.[20] These concerns were applicable to other vaccines as well, with the overall belief of advancing one's own health through natural means.[20] In a demographically representative sample of the US population, Black respondents were significantly less likely to get vaccinated compared to non Black respondents (44% vs 64% respectively).[21] Similarly, in a study examining the correlates for vaccine hesitancy, Blacks, women, and conservative political ideology were negatively correlated with vaccine uptake.[22] Common reasons for not getting vaccinated were a lack of trust and concerns about the effectiveness of the vaccine. Lack of financial resource and insurance were among the factors contributing to hesitancy among Blacks compared to Whites. Effective public health messaging is needed in under-resourced communities to increase vaccine acceptance and reduce subsequent mortality from the infection.[19] Mistrust in the current health system is a huge barrier to vaccination and the past atrocities of American medical system towards African Americans needs to be acknowledged and recognized. [19]

Other barriers mitigating uptake of COVID-19 vaccine includes lack of technical literacy.[17] Lack of computer skills and internet can prevent uneducated and less well-off adults from receiving the vaccine.[17] Internet access is less prevalent among communities affected most by the pandemic such as the elderly, communities of color such as Black, Latinx, Native American, and those living in rural areas.[17] In addition, the process of making appointment to get vaccinated requires trust and time.[23] Lack of digital connection, time to refresh internet websites for appointments and hold on to the phone for hours, and inability to travel to vaccination sites can all hinder vaccination efforts.[23]

Conspiracy beliefs regarding COVID-19 pandemic, vaccinations, and precautionary means are more prevalent in politically conservative individuals or disadvantaged racial groups.[24] In a survey of 1,050 US adults assessing topics such as preventive measures to the pandemic, vaccine intentions, political ideology etc., conspiracy theory beliefs were negatively related to intentions to get vaccinated. Younger individuals with lower income and education were more likely to hold such beliefs about the pandemic. The survey also reported that non-white respondents were more likely to believe in conspiracy theories. Persistence of non-compliance through conspiracy beliefs remains an obstacle to the control of the pandemic.[24] Confronting such beliefs will need to be aided by news journalists, especially those with politically conservative audiences.[24] However, we must be careful branding vaccine-hesitant persons as "conservative", as this would imply that vaccines are a liberal concept and further promote non-compliance in conservative people. Furthermore, this leads to individuals that are hesitant to receiving vaccines for reasons such as distrust in the medical community from being heard.[25]

Campaigns delivering vaccines must consider both structural and attitudinal barriers surrounding vaccines discussed above.[26] Endorsements from both local and internationally recognized health agencies can be vital in increasing uptake of COVID-19 vaccines. The use of social media can be beneficial in promoting vaccination. In a study of American and Canadian adults, 96% said they would be willing to get a vaccine if it were promoted within their social media networks.[26] Encouraging individuals who have gotten vaccinated to post their experiences on social media can also increase in uptake.[26] Concerns surrounding the rapid development and testing process remains a large barrier to vaccination.[16] To address this issue, the public should be informed about the careful process of testing and ongoing monitoring needed for vaccine roll

out.[16] Furthermore, educational campaigns should stress the importance of how individuals getting vaccinated contribute to herd immunity.[16] Transparency regarding vaccine effectiveness and adverse events should be made clear to the public to improve trust, but such messaging should limit overemphasizing the risk of rare events.[16] In a recent study in African American individuals (n=110), higher trust in vaccine advice from physicians of the same race as opposed to physicians from other race was seen.[27] Higher trust in disease survivors, school nurses, and parents was also seen, suggesting that such diversity outside of the conventional medical and public health community is needed to overcome vaccine hesitancy and barriers.[16]

In the age of social media, false information can spread quickly and it is important that the health community mitigates such dissemination.[16] Correcting information on social media either from commenting or posting links to evidence-based information can be effective in changing beliefs.[28] Ultimately, countering false information needs to take place quickly, before false information surrounding vaccines takes root in the public.[28]

Manuscript 1

Demographic benchmarks for equitable coverage of COVID-19 vaccination

Kushagra Vashist, BS[1] Tabia Akintobi, PhD, MPH[2] Robert A. Bednarczyk, PhD, MS[1,3] KM Venkat Narayan, MD, MSc, MBA[1,3] and Shivani A. Patel, PhD, MPH[1,3]*

[1]Department of Epidemiology, Rollins School of Public Health, Emory University, Atlanta, GA

[2] Department of Community Health and Preventive Medicine, Morehouse School of Medicine, Atlanta, GA

[3]Hubert Department of Global Health, Rollins School of Public Health, Emory University, Atlanta, GA

Background

After a year of unprecedented social distancing and over 530,000 American deaths due to COVID-19, three SARS-COV-2 vaccines are authorized for emergency use. Federal and state authorities based vaccination priorities on employment in high-exposure occupations essential to everyday life and vulnerability to severe COVID-19 disease.[1] By virtue of employment in high-risk occupations [3] and experience of severe COVID-19 disease and death [29], people of color especially Black, Hispanic, and Native Americans—are thus expected to be prioritized for early vaccination. Yet, reports suggest that public vaccination sites are less likely to be in communities of color in the South[5] and that racial and ethnic minorities are overall more hesitant than whites to take the vaccine [30]. Understanding the demographic composition of the US population prioritized for vaccination is critical to track equity in vaccine coverage and to better tailor health communication strategies.

Objective

The racial and ethnic, age, sex, and regional distribution of non-institutionalized populations prioritized for COVID-19 vaccination are reported.

Methods

Classification of Phase 1 and 2 priority populations follow the Advisory Committee on Immunization Practices (ACIP) criteria. [1] The demographic composition of non-institutionalized priority populations was estimated using the nationally representative National Health Interview

Survey (NHIS; n=25,417) conducted in 2018, the most recent data with necessary occupational, medical history, and demographic information. Whereas ACIP recommended essential healthcare workers at high risk of coronavirus exposure for Phase 1a, we classified all healthcare workers in Phase 1a due to data constraints. Non-healthcare essential workers and adults 75 years and older were classified as Phase 1b. Essential workers not covered in Phase 1a or 1b, adults aged 65-74, and adults aged 18-64 with a high-risk medical condition for COVID-19 were classified as Phase 1c. All other individuals were in Phase 2. Analyses were conducted using SAS 9.4 software (SAS Institute Inc., Cary, NC).

Results

Approximately 85% of US adults fall into Phase 1 and 15% fall into Phase 2 of the vaccine priority schedule (Table). Relative to the US population, Phase 1a has a larger share of women (74%), non-Hispanic Black individuals (18%), and adults aged 25-44 years (41%). Phase 1b has a more equal gender balance (49% women), larger proportion of Non-Hispanic Whites (70%), and by design, adults aged 75 years and older (35%). The demographic distribution of Phase 1c largely follows that of the overall US population. Phase 2 consists of a larger proportion of men (54%), adults aged 18-24 y and 25-44 y, and Hispanic Americans (24%) compared to the overall US population.

Discussion

A relatively large fraction of individuals prioritized for the earliest distribution of the vaccine are women, non-Hispanic Black, and young to middle-aged adults. While Black adults are expected to be 17% of Phase 1a, they comprised only 5.4% of adults vaccinated in the first month of the US vaccination program[30] and 6.8% of fully vaccinated adults three months after authorization.[31] Furthermore, the proportion of Black adults vaccinated is lower than their share of the population in at least 30 of 44 states reporting vaccination data by race.[32] Delivering vaccines to priority populations will rely on increased investments in overcoming barriers to vaccine access (such as transportation to vaccine centers, internet access to make appointments, and time off of work) and communication strategies that address vaccine hesitancy in vulnerable groups. Native Americans—a priority group due to exceedingly high COVID-19 mortality—comprise a greater share of those vaccinated (~1.5%[33]) than their representation in the US population (~0.8%). This success demonstrates that systematic efforts can overcome challenges in reaching vulnerable communities. Eligibility for vaccination is ultimately determined by states, and heterogeneity in the timing of eligibility (e.g., teachers, caregivers and co-residents of elderly) must be considered for local benchmarking. Beyond national data on vaccination demographics,[33] state- and county-level data to track and address the demographic gap between those who received the COVID-19 vaccine versus those prioritized for vaccination will be critical for an equity-oriented course correction in the US pandemic response.

Limitations

Estimates are based on 2018 data. Data constraints imposed the following additional limitations: Phase 1a estimates included all healthcare workers (irrespective of essential classification); estimates exclude individuals in long-term care facilities and incarcerated populations; some

Phase 1b and 1c occupations and morbidities were not captured.

Table. Distribution of the non-institutionalized adult COVID-19 vaccination priority populations by sex, race/ethnicity, age and region.

Demographics	Total Non-Institutionalized US Population	Prioritized under Phase 1			Prioritized under Phase 2[d]
		Phase 1a[a]	Phase 1b[b]	Phase 1c[c]	
	% (95 % CI)	% (95 % CI)	% (95 % CI)	% (95 % CI)	% (95 % CI)
Number of adults, n	249,455,533	22,074,002	54,313,310	135,955,691	37,112,530
Sex					
Men	48.3 (47.5, 49.0)	26.2 (24.0, 28.4)	51.4 (49.9, 52.9)	49.1 (48.1, 50.2)	53.5 (51.3, 55.7)
Women	51.7 (51.0, 52.5)	73.8 (71.6, 76.0)	48.6 (47.1,50.1)	50.9 (49.8, 51.9)	46.5 (44.3, 48.7)
Race & Ethnicity					
Non-Hispanic White	63.0 (61.5, 64.6)	61.6 (58.7, 64.6)	70.2 (68.1, 72.2)	62.9 (61.2, 64.6)	54.1 (51.3, 56.9)
Non-Hispanic Black	11.7 (10.8, 12.6)	17.5 (15.1, 19.9)	9.7 (8.6, 10.8)	11.6 (10.6, 12.6)	11.3 (9.6, 13.1)
Hispanic	16.3 (15.0, 17.7)	10.6 (8.7, 12.4)	13.5 (11.8, 15.1)	16.2 (14.8, 17.6)	24.1 (21.6, 26.7)
American Indian and Alaskan Native	0.8 (0.4, 1.2)	0.9 (0.2, 1.5)	0.5 (0.09, 1.0)	1.0 (0.5, 1.4)	0.6 (0.2, 1.0)
Asian	6.1 (5.4, 6.7)	7.8 (6.1, 9.4)	4.6 (3.8, 5.4)	5.9 (5.2, 6.6)	7.9 (6.7, 9.1)
Other	2.1 (1.8, 2.3)	1.6 (1.03, 2.3)	1.5 (1.1, 1.9)	2.4 (2.0, 2.7)	2.0 (1.2, 2.6)
Age					
18 to 24 years	11.7 (11.1, 12.4)	6.7 (5.1, 8.3)	6.3 (5.3, 7.3)	10.5 (9.7,11.3)	27.1 (25.0, 29.3)
25 to 44 years	34.4 (33.5, 35.2)	41.4 (38.9, 43.9)	23.7 (22.3, 25.0)	34.5 (33.4, 35.6)	45.5 (43.3, 47.7)
45 to 64 years	33.3 (32.5, 34.0)	34.9 (32.4, 37.4)	24.3 (23.0, 25.7)	38.2 (37.2, 39.2)	27.4 (25.3, 29.4)
65 to 74 years	12.4 (11.9, 12.8)	10.7 (9.4, 12.0)	10.3 (9.4, 11.2)	16.8 (16.1, 17.5)	.
75 years and above	8.2 (7.9, 8.7)	6.2 (5.2, 7.2)	35.4 (33.9, 36.9)	.	.
Census Region[e]					
Northeast	17.3 (16.5, 18.2)	20.9 (18.7, 23.2)	17.0 (15.6, 18.3)	17.0 (16.0, 18.1)	16.9 (15.1, 18.8)
North Central/Midwest	22.0 (21.1, 22.8)	21.2 (19.2, 23.2)	24.8 (23.3, 26.3)	21.2 (20.2, 22.2)	21.1 (19.1, 23.1)
South	36.9 (35.8, 38.0)	37.4 (34.8, 40.0)	35.8 (34.0, 37.5)	37.6 (36.2, 39.0)	35.5 (33.0, 37.9)
West	23.8 (22.7, 24.9)	20.4 (18.4, 22.5)	22.4 (20.8, 24.1)	24.1 (22.9, 25.4)	26.5 (24.0, 28.9)

Note: Phases are assigned according to the CDC COVID-19 Vaccination Program Interim Playbook for Jurisdiction Operations framework.

[a] Estimation of Phase 1a demographics included as all healthcare workers (regardless of essential status) and did not include institutionalized populations (i.e., long-term care facility residents or incarcerated individuals). Note: ACIP defined Phase 1a as essential healthcare workers and long-term care residents.

[b] Estimation of Phase 1b demographics included individuals 75 years and older and non-healthcare essential workers. Phase 1b estimates exclude individuals who are prioritized in Phase 1a.

[c] Estimation of phase 1c demographics included essential workers not covered in phase 1a or 1b, adults aged 65 to 74, and individuals aged 18-64 with high-risk medical conditions. Phase 1c estimates exclude individuals who are prioritized in Phase 1a or Phase 1b.[34]

[d] Comprises all individuals not covered in prior phases.

[e] Northeast: ME, NH, VT, MA, RI, CT, NY, NJ, PA; North Central/Midwest: MI, OH, IN, IL, WI, MN, IA, MO, ND, SD, KS, NE; South: DE, MD, DC, VA, WV, NC, SC, GA, FL, KY, TN, MS, AL, TX, AR, OK, LA; West: WA, AK, OR, CA, HI, MT, ID, WY, CO, NM, AZ, UT, NV

Supplemental Information

Phase 1a includes critical healthcare workers (Health diagnosing and treating practitioners, health technologists and technicians, other healthcare practitioners and technical occupations, nursing, psychiatric, and home health aides, occupational and physical therapist assistants and aides, other healthcare support occupations, funeral service workers) as per ACIP.

Phase1b includes non-healthcare critical workers (First-line managers/supervisors, protective service workers, firefighting and prevention workers, law enforcement workers, other protective service workers, animal care and service workers, primary, secondary, and special education school teachers, post-secondary teachers, other teachers and instructors, supervisors, farming, fishing, and forestry workers, agricultural workers, fishing and hunting workers, food processing workers, assemblers and fabricators, metal workers and plastic workers, other production occupations, supervisors, production workers, motor vehicle operators, electrical and electronic equipment mechanics, installers and repairers, and woodworkers), adults aged 75 and older not already covered in phase 1a.

Phase1c includes essential workers not previously covered in phase 1a or 1b (Chief executives; general and operations managers; legislators, advertising, marketing, promotions, public relations, and sales managers, operations specialties managers, other management occupations, business operations specialists, financial specialists, mathematical science occupations, architects, surveyors, and cartographers, engineers, drafters, engineering, and mapping technicians, life scientists, physical scientists, social scientists and related workers, Life, physical, and social science technicians, religious workers, counselors, social workers, and other

community and social service specialists, lawyers, judges, and related workers, legal support workers, librarians, curators, and archivists, other education, training, and library occupations, media and communication workers, media and communication equipment workers, supervisors, food preparation, and serving workers, cooks and food preparation workers, food and beverage serving workers, other food preparation and serving related workers, supervisors, building and grounds cleaning and maintenance workers, building cleaning and pest control workers, grounds maintenance workers, supervisors, personal care and service workers, transportation and logistics, tourism, and lodging attendants, supervisors, sales workers, retail sales workers, sale representative, services, sale representative, wholesale and manufacturing, other sales and related workers, supervisors, office and administrative workers, communications and IT equipment operators, financial clerks, information and record clerks, material recording, scheduling, dispatching, and distributing workers, secretaries and administrative assistants, other office and administrative support workers, forest, conservation, and logging workers, supervisors, construction and extraction workers, construction trades workers, helpers, construction trades, other construction and related workers, extraction workers, supervisors of installation, maintenance, and repair workers, vehicle and mobile equipment mechanics, installers, and repairers, other installation, maintenance, and repair occupations, printing workers, textile, apparel, and furnishing workers, plant and system operators, supervisors, transportation and material moving workers, air Transportation and logistics workers, rail transportation and logistics workers, water transportation and logistics workers, other transportation and logistics workers, material moving workers), adults aged 65-74 years, and individuals aged 18-65 with one or more of the following comorbidities: Cancer, type 2 diabetes, CKD, COPD, Obesity (BMI>=30), heart condition, asthma, stroke, hypertension, dementia, liver disease as per ACIP.

Phase 2 consists of all workers not covered in prior phases. This includes computer specialists, arts and design workers, entertainers and performers, sports and related workers, entertainment attendants and related workers, personal appearance workers, military and all individuals whose occupations could not be ascertained.

Manuscript 2

Identification of groups at high risk for under-coverage of adult vaccinations: A national study to inform COVID-19 response

Kushagra Vashist, BS[1] Daesung Choi, PhD[2] and Shivani A. Patel, PhD, MPH[1,2]*

[1]Department of Epidemiology, Rollins School of Public Health, Emory University, Atlanta, GA

[2]Hubert Department of Global Health, Rollins School of Public Health, Emory University, Atlanta, GA

Abstract

Objectives

To inform expectations around the ongoing vaccination effort, we analyzed flu vaccine uptake in groups prioritized for COVID-19 vaccination and examined the role of socio-demographic and behavioral factors in differences in receiving flu vaccine.

Methods

Using the 2018 National Health Interview Survey, we classified 24,772 adults into four COVID-19 vaccination priority groups: Healthcare workers, medically vulnerable, non-healthcare essential workers, and the general population. We performed multiple logistic regression to compare the relative odds of receiving flu vaccine by priority groups, and socio-demographic and health-related factors of interest.

Results

Healthcare workers, medically vulnerable adults, essential workers, and the general population comprise 8.9%, 58.4%, 6.6%, and 26.1 % of the US population, respectively. Compared with healthcare workers, the adjusted odds ratio (aOR) of receiving flu vaccine were significantly lower in medically vulnerable adults (aOR=0.43, 95% CI=0.37, 0.48), essential workers (aOR=0.28, 95% CI=0.23, 0.34), and the general population (aOR=0.32, 95% CI=0.28, 0.37). Being young, male, Black, and having no health insurance were associated with lower relative odds of receiving the flu vaccine.

Conclusions

Patterns of seasonal flu vaccine portend slower coverage of the COVID-19 vaccine across the US as eligibility expands to the general population.

Introduction

Since December 2020, three vaccines for the prevention of COVID-19 have been authorized for emergency use by the Food and Drug Administration (FDA) and 18% of the US population is fully vaccinated. Earliest prioritization for vaccine allocation was based on the goal of protecting Americans who are employed in high-exposure occupations needed for public wellbeing and protecting Americans who are most vulnerable to severe outcomes such as hospitalization and death.[34] The ultimate goal of vaccination, however, is to reduce circulation of the virus to achieve herd immunity, which is essential for the resumption of normalcy.[2] This will require vaccinating a critical mass of individuals—estimated at over 80% of the US population.[35] There are limited population-based data regarding factors impacting receipt of the COVID-19 vaccination among the 70% of the US adult population not yet fully vaccinated.[33]

Currently, 14 states have administered less than 75% of the vaccines allocated to them.[36] Identifying potential facilitators and barriers to vaccination in groups beyond those prioritized in the earliest phase will therefore be important to achieving national vaccination targets. The US experience with the seasonal influenza vaccine may provide useful insight on expected behaviors regarding COVID-19 vaccination. Both flu and COVID-19 vaccines target adult populations and require similar infrastructure for distribution and vaccination. Recent studies have demonstrated that demographic patterns of attitudes and behaviors regarding uptake of the seasonal influenza vaccine may be similar to attitudes and behaviors for the COVID-19 vaccine. For instance, early data show a correlation between having received the annual flu vaccine and COVID-19 vaccine acceptability among Black Americans and older adults.[9] Furthermore, flu vaccine uptake was significantly associated with higher acceptability COVID-19 vaccination in a national study,[10] suggesting that flu vaccination may be a good proxy for attitudes regarding the COVID-19

vaccine. To inform expectations around COVID-19 vaccination for the remainder of the roll-out, we examined differences and likelihood of getting flu vaccine by commonly identified priority groups, including healthcare workers, medically vulnerable, non-healthcare essential workers, and the general population. We also examined the role of socio-demographic and behavioral factors in differences in receiving flu vaccine.

Methods

Data and sample

The National Health Interview Survey (NHIS) is a cross-sectional, representative household interview survey which collects information on the health of non-institutionalized US population across the 50 states through the use of a complex multistage design.[37] We used the publicly available 2018 NHIS adults sample data to obtain report of flu vaccine uptake, detailed occupational codes, chronic disease and other basic socioeconomic and demographic characteristics. Our study was restricted to respondents aged 18-85 (n=25,417). Respondents with missing information on any study variable were excluded from analysis, resulting in an unweighted analytic sample size of 24,772 (2.5% excluded due to missing data).

Outcome

Our outcome was flu vaccine uptake, measured as a binary variable describing whether or not the respondent received the flu vaccine in the past 12 months.

Vaccination priorities and eligibility

Advisory Committee of Immunization Practices (ACIP) framework [1] recommended three criteria for determining phased priorities for vaccination: employment in the healthcare field, medical

vulnerability (including the elderly), and employment in other essential occupations. States however exercised discretion in determining eligibility.[38] To provide a picture of how different priority groups may respond to the vaccine campaign, we categorized US adults into four broad groups that have commonly been used to determine eligibility for vaccination thus far: Healthcare workers, the medically vulnerable, essential occupations outside of healthcare, and the remaining general population.[1] Healthcare workers included all healthcare-related occupations identified in NHIS 2018, such as healthcare practitioners, nurses, funeral service workers etc. The medically vulnerable group included adults who had one or more high risk medical conditions for COVID-19, including cancer, type 2 diabetes, chronic kidney disease, chronic obstructive pulmonary disease, obesity body mass index>=30), heart condition, asthma, stroke, hypertension, dementia, liver disease and also adults over the age of 65 who were not already covered in the healthcare group. Other essential occupations included adults who were not already covered in the healthcare or medically vulnerable group and those employed in occupations critical to the daily functioning of America, such as first responders, teachers, retail store workers, food and agriculture workers, manufacturing workers, and motor vehicle operators. The general population included all other adults over the age of 18 not included in another group.

Factors potentially impacting adult vaccine uptake

We considered several demographic, socioeconomic, and health factors in the analysis. Demographic characteristics were age at interview (categorized as five groups: 18-24, 25-44, 45-64, 65-74, and 75 and above), gender (men and women), race/ethnicity (Non-Hispanic Whites, Non-Hispanic Blacks, Hispanics, Asians, American Indians and Native Alaskans, and Others), and place of birth (US-born and foreign-born). Socioeconomic factors included combined family

income in USD (less than $30,000, $30,000-$60,000, $60,000-$100,000, and $100,000 and above), educational attainment (high school or less, less than 4 years of college, and 4 or more years of college). Factors related to healthcare behaviors included smoking behavior (smoker, former smoker, and never-smoker), health Insurance (some health insurance, no health insurance), and past use of internet to research health information (yes/no), and history of delaying healthcare due to lack of transportation (yes/ no). We also included region (Northeast, Midwest/Central, South, and West) to provide insight into differences across the United States.

Statistical Analysis

We first described the composition of priority populations for vaccination by four priority groups as defined above. To investigate the association between flu vaccine uptake and priority groups, socio-demographic and health-related behavioral factors, we performed two multiple logistic regression models; unadjusted model only considered the crude associations between flu vaccine uptake and the four priority groups, and correlates of interest. Adjusted model included priority groups and all covariates under consideration. All analyses were conducted using SAS 9.4 software (SAS Institute Inc., Cary, NC) accounting for the complex survey design of NHIS.

Results

Table 1 shows the demographic composition of US adults classified by COVID-19 vaccination priority group. A total of 9% adults were classified as healthcare workers, 58% as medically vulnerable, 7% essential workers, and 26% as the general population. All demographic, socioeconomic, and health characteristics were significantly different by priority group (p-value <0.001). Among healthcare workers, the majority were female, whereas all other categories had

a relatively even gender distribution. Healthcare workers had an almost even share of older and younger adults, medically vulnerable population had a majority of adults over the age of 45, and essential workers and the general population mostly had individuals under 45. Healthcare workers, medically vulnerable, and essential workers all had similar percentage of Non-Hispanic Whites compared to the general population, which had a slightly lower percentage of Whites. Healthcare workers were the most educated, and the medically vulnerable, the least. Healthcare workers and the general population earned the most income, followed by essential workers, and medically vulnerable.

Figure 1 shows the prevalence of receiving the seasonal flu vaccine stratified by priority classification. Overall, 45% of US adults (95% CI= 43.8, 45.7) reported receiving the flu vaccine in the last 12 months. The prevalence of receiving the flu vaccine in the past 12 months was highest in healthcare workers (66.2%, 95% CI=63.7, 68.8) followed by medically vulnerable (48.7%, CI= 47.6, 49.8), and lowest in essential healthcare workers (29.1%, 95% CI=26.2, 30.0) and the general population with 32.5% (95% CI= 30.9, 34.1).

Tables 2 shows the unadjusted and adjusted associations of priority classification, demographic, socioeconomic, and health characteristics with receiving seasonal flu vaccine. Compared with healthcare workers, the unadjusted odds ratio (OR) of flu vaccine uptake was OR=0.48 (95% CI=0.43, 0.54) for the medically vulnerable population, OR=0.21 (95% CI=0.18, 0.25) for essential occupations, and OR= 0.25 (95% CI= 0.22, 0.28) for the general population. These associations remained largely unchanged after adjusting for several demographic, socioeconomic, and healthcare variables.

We observed several statistically significant demographic, socioeconomic, and healthcare correlates of receipt of flu vaccine in the past 12 months. In fully adjusted models, younger age (adjusted ORs [aOR] ranging from 0.18 to 0.63 relative to ages 75 and above), being male (aOR=0.82, 95% CI= 0.77, 0.88), being Non-Hispanic Black (aOR= 0.78, 95% CI= 0.69, 0.88), lower income (aOR ranging from 0.75 to 0.83 relative to $100,000 or more) and lower educational attainment (high school or less aOR=0.75, 95% CI=0.68, 0.82; less than 4 years of college aOR=0.71, 95% CI= 0.65, 0.78) were inversely associated with receiving the flu vaccine in the past 12 months. Health behaviors inversely associated flu vaccine included not researching health related information on the internet (aOR=0.84, 95% CI=0.78, 0.91), being current smoker (aOR=0.63, 95% CI=0.57, 0.70), and not having health insurance (aOR= 0.36, 95% CI=0.31, 0.42). Identifying as American Indian or Native Alaskan was significantly associated with higher vaccine uptake (aOR=1.47, 95% CI= 1.04, 2.07).

Discussion

The goal of this study was to provide timely data to describe barriers to vaccination coverage in priority populations for COVID-19, highlighting potential areas that federal and state authorities could address to increase COVID-19 vaccine uptake. We approached this issue by evaluating prior flu vaccine uptake by COVID-19 vaccination priority groups in a nationally representative sample of US adults. While 45% of all US adults reported receiving flu vaccine in the past 12 months, uptake varied from a low of 30% in essential workers to a high of 65% in healthcare workers. These differences in flu vaccine uptake by priority classification remained even after accounting for demographic, socioeconomic, and health factors. Importantly, compared to health care workers, individuals in medically vulnerable group, essential non-healthcare occupations and general population were less than half as likely to have received flu vaccine. Collectively,

these findings suggest that COVID-19 vaccination in adults with medically vulnerability, employed in essential non-healthcare occupations and in the general population may be more challenging than delivering vaccinations in healthcare workers. This may be a major barrier to reaching herd immunity given that essential non-healthcare workers and the general population category make up 33% of the total adult population.[39]

In addition, we identified several demographic and health facilitators of vaccine uptake. We found that younger age groups, men, those with lower socio-economic status, and without health insurance had lower odds of receiving flu vaccine. Having used the internet to research health related information was a statistically significant predictor of having received the flu vaccine. Prior use of internet may also impact COVID-19 vaccination coverage, given the complex web-based appointment systems that have emerged across states.

Adults identifying as Black/African American were less likely to have received a flu vaccine in the past year, reiterating concerns about reaching this population in the COVID-19 vaccination campaign.[40] We also tested the effect of health care delay due to transportation on flu vaccination, but was not statistically significant. However, previous literature has emphasized the importance of ease of transportation in increasing uptake. Other factors such as language barriers as well as making vaccines readily accessible in nonmedical outlets and accommodating individuals with incomplete immunization records could be vital in increasing uptake as well.[11]

Vaccination uptake may be hindered by both systemic barriers, such as access, and individual barriers, vaccine hesitancy. Our findings show that the subgroups who were less likely to receive the flu vaccine are the same groups that are expected to experience substantial systemic and individual barriers to vaccine uptake, such as low-income and less educated individuals. In

addition people of color are at a higher risk of COVID-19 infection, hospitalization, and death.[41] For example, public vaccine distribution centers are less likely to be located in communities of color.[18] and minority groups may be more hesitant to take the vaccine, due partly to mistrust generated through history of mistreatment, accelerated development of the vaccine, and side effects.[20]In a recent study reporting that Black respondents were significantly less likely to get vaccinated for COVID-19 compared to non-Black respondents (44% vs. 64% respectively).[21]Similarly, in a study examining the correlates for vaccine hesitancy, identifying as Black was negatively correlated with vaccine uptake [22]. Common reasons for not getting vaccinated were a lack of trust and concerns about the effectiveness of the vaccine. Lack of financial resource and insurance were among the factors contributing to lack of uptake among Blacks compared to Whites. Issues surrounding lack of trust can explain some of the disparities in influenza vaccine uptake beyond structural barriers and it is likely that such issues will also have an impact on COVID-19 vaccine uptake. [26]

A strength of the study was our use of the most recent nationally representative data to quantify facilitators and barriers of prior vaccination uptake among US adults. We used ACIP criteria for priority groups to partition the US population into commonly used categories determining COVID-19 vaccination, to offer insight on how vaccination may unfold across the categories. Several limitations of this study should be acknowledged. We could not analyze institutionalized adults (e.g., those living in nursing homes or prisons) as NHIS does not target institutionalized populations. Our healthcare worker category included all healthcare-related occupations in NHIS (i.e., we were not able to restrict to the specific healthcare occupations defined by ACIP). Furthermore, we could not analyze some specific occupations as proposed by ACIP for the essential care worker category, due to lack of specificity in the public-use occupational data.

Although the literature supports treating influenza vaccine experience as informative for COVID-19 vaccine [40], there may be differences between the acceptances of two types of vaccines which cannot be assessed in this study.

An estimated 80% of the US population is needed to be vaccinated in order to achieve herd immunity to SARS-Cov-2. Anticipating the subgroups in which adult vaccine uptake is low is an important dimension of developing strategies to reach these groups. Our findings reinforce previous data that men, Blacks, and those without insurance have historically been less likely to receive adult vaccines such as the flu vaccine; and these patterns may provide a baseline to inform constraints to receiving COVID-19 vaccine– both at an individual level and system level.

Public Health Implications

An estimated 80% of the US population is needed to be vaccinated in order to achieve herd immunity to SARS-Cov-2. Anticipating the subgroups in which adult vaccine uptake is low is an important dimension of the federal, state, and county strategies to achieve these national targets. Our findings reinforce previous data that younger adults, men, Black Americans, and those without insurance may be particularly vulnerable to under-coverage of COVID-19 vaccination. We also observed that all priority groups subsequent to healthcare workers were less likely to receive seasonal flu vaccines. In particular, Americans working in essential occupations and members of the general population who were not prioritized in the earliest phases of COVID-19 vaccine rollout may require additional efforts to attain desired coverage. Evidence-based and tailored communication strategies and vaccination delivery policies must be implemented to directly address barriers to COVID-19 vaccine uptake among adult populations with a history of lower coverage of recommended vaccinations in this country.

Tables and Figures

Table 1. Demographic composition of US adults overall and classified by COVID-19 vaccination priority groups, NHIS 2018

	All adults	Healthcare[a]	Medically[b] vulnerable	Non-healthcare[c] Essential workers	General population[d]	p-value
Unweighted N	24,772	2,210	15,604	1,114	5,844	
Weighted N	242,253,193	21,491,779	141,370,244	16,085,898	63,305,272	
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	
		8.9 (8.4, 9.3)	58.4 (57.5, 59.2)	6.6 (6.2, 7.1)	26.1 (25.3, 26.9)	
Age						<0.001
18-24	11.7 (11.0, 12.3)	6.8 (5.2, 8.4)	7.4 (6.7, 8.0)	22.2 (19.1, 25.4)	20.2 (18.8, 21.7)	
25-44	34.3 (33.5, 35.2)	41.5 (39.0, 44.1)	25.5 (24.5, 26.5)	46.7 (43.6, 49.8)	48.5 (46.9, 50.2)	
45-64	33.3 (32.5, 34.0)	34.7 (32.2, 37.2)	34.2 (33.3, 35.2)	31.1 (28.2, 33.9)	31.3 (29.7, 32.8)	
65-74	12.4 (11.9, 12.9)	10.7 (9.4, 12.0)	19.6 (18.9, 20.4)	.	.	
75+	8.3 (7.9, 8.7)	6.3 (5.2, 7.3)	13.3 (12.7, 13.9)	.	.	
Male	48.3 (47.5, 49.1)	26.2 (24.0, 28.5)	49.9 (49.0, 50.9)	50.6 (47.2, 54.0)	51.6 (50.1, 53.2)	<0.001
Race/ethnicity						<0.001
Asian	6.00 (5.4, 6.6)	7.7 (6.0, 9.4)	4.1 (3.6, 4.7)	6.3 (4.6, 8.0)	9.5 (8.3, 10.7)	
Non-Hispanic White	63.5 (61.9, 65.1)	62.0 (59.1, 64.8)	66.9 (65.2, 68.5)	61.8 (58.1, 65.5)	56.9 (54.7, 59.1)	
Non-Hispanic Black	11.5 (10.6, 12.3)	17.0 (14.7, 19.3)	11.3 (10.3, 12.3)	9.6 (7.5, 11.7)	10.5 (9.2, 11.8)	
Hispanic	16.1 (14.8, 17.5)	10.7 (8.9, 12.6)	14.4 (13.1, 15.8)	20.8 (17.6, 23.9)	20.7 (18.8, 22.7)	
American Indian and Alaskan Native	0.8 (0.4, 1.2)	0.9 (0.2, 1.5)	0.9 (0.5,1.3)	0.5 (0.0, 1.0)	0.6 (0.3, 0.9)	
Other	2.1 (1.8, 2.4)	1.7 (1.1, 2.4)	2.4 (2.0, 2.7)	1.0 (0.2, 1.9)	1.8 (1.3, 2.3)	
US born	81.0 (79.8, 82.1)	81.5 (79.0, 84.0)	84.9 (83.7, 86.0)	74.0 (70.7, 77.3)	73.9 (72.0, 75.7)	<0.001
Combined Family Income in USD						<0.001
0-29,999	20.9 (20.0, 21.7)	17.6 (15.9, 19.4)	23.2 (22.2, 24.1)	18.1 (15.7, 20.5)	17.5 (16.2, 18.7)	
30,000-59,999	23.5 (22.7, 24.3)	22.1 (19.8, 24.3)	25.1 (24.2, 26.0)	22.7 (20.0, 25.5)	20.7 (19.2, 22.1)	
60,000-99,999	23.0 (22.3, 23.7)	21.5 (19.4, 23.6)	23.4 (22.5, 24.2)	23.9 (21.3, 26.5)	22.3 (21.0, 23.8)	
100,000+	32.6 (31.5, 33.8)	38.8 (36.3, 41.3)	28.3 (27.1, 29.4)	35.2 (31.9, 38.6)	39.5 (37.6, 41.4)	
Educational attainment						<0.001
High school or less	35.8 (34.7, 36.8)	17.3 (15.4, 19.2)	39.9 (38.8, 41.1)	35.5 (32.1, 39.0)	32.7 (31.0, 34.5)	
< 4 years college	30.6 (29.8, 31.4)	38.9 (36.2, 41.5)	30.2 (29.2, 31.0)	30.0 (26.9, 33.1)	28.9 (27.4, 30.4)	

4 years of college or more	33.6 (32.6, 34.7)	43.8 (41.2, 46.5)	29.9 (28.8, 31.0)	34.4 (31.3, 37.6)	38.4 (36.4, 40.3)	
Smoking behavior						<0.001
Never	64.0 (63.2, 64.9)	69.1 (66.9, 71.4)	58.1 (57.1, 59.1)	72.2 (69.4, 75.1)	73.6 (72.1, 75.0)	
Current smoker	13.7 (13.1, 14.3)	10.5 (9.1, 12.0)	14.7 (14.0, 15.4)	14.2 (12.0, 16.5)	12.5 (11.4, 13.6)	
Former	22.2 (21.6, 22.9)	20.3 (18.4, 22.2)	27.2 (26.3, 28.1)	13.5 (11.5, 15.6)	13.9 (12.9, 15.0)	
Has health Insurance	89.7 (89.1, 90.4)	93.6 (92.4, 94.9)	91.6 (90.9, 92.3)	85.7 (83.8, 88.7)	85.3 (84.0, 86.6)	<0.001
Researched health information on internet	55.6 (54.6, 56.6)	67.0 (64.4, 69.5)	52.8 (51.7, 54.0)	55.1 (51.9, 58.4)	58.1 (56.3, 59.9)	<0.001
Delayed healthcare due to transportation	2.3 (2.1, 2.6)	2.5 (1.6, 3.3)	3.0 (2.6, 3.3)	1.2 (0.5, 1.9)	1.2 (0.8, 1.6)	<0.001
Region						<0.001
Northeast	17.2 (16.3, 18.1)	20.9 (18.6, 23.2)	16.6 (15.7, 17.6)	13.9 (11.4, 16.4)	18.1 (16.5, 19.6)	
Midwest	22.2 (21.3, 23.0)	21.5 (19.4, 23.6)	22.1 (21.2, 23.1)	25.9 (22.8, 28.9)	21.4 (19.8, 23.0)	
South	36.9 (35.8, 38.1)	37.5 (34.9, 40.1)	38.5 (37.2, 39.7)	33.0 (29.6, 36.3)	34.2 (32.3, 36.2)	
West	23.7 (22.6, 24.8)	20.1 (18.2, 22.1)	22.7 (21.5, 23.9)	27.3 (23.7, 30.8)	26.3 (24.4, 28.2)	

Demographic characteristics as weighted prevalence (95% CI) for the whole sample, healthcare workers, medical vulnerable, essential workers, and the general population.

[a] Comprises healthcare workers and does not include institutionalized populations (i.e., long-term care facility residents or incarcerated individuals).

[b] Comprises individuals 65 years and older and individuals aged 18-64 with at least one medical comorbidity.

[c] Comprises non-healthcare essential workers.

[d] Comprises all individuals not covered in prior categories.

Priority categories are assigned according to the CDC COVID-19 Vaccination Program Interim Playbook for Jurisdiction Operations framework. See supplementary methods for further detail on the composition of region and healthcare workers, medically vulnerable individuals, non-healthcare essential workers, and general population.

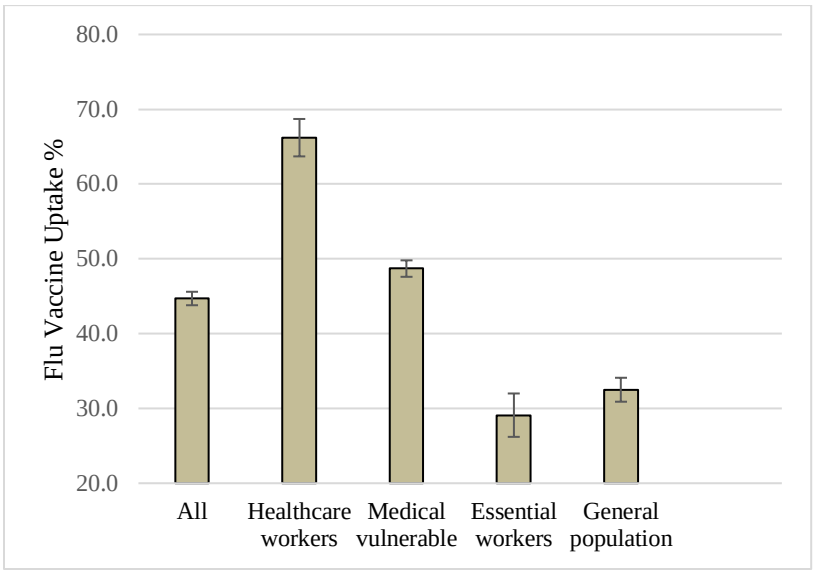
Table 2. Logistic regression examining unadjusted and adjusted associations between flu vaccine uptake and priority groups, and socio-economic and health-related factors, NHIS 2018

	Unadjusted associations*		Adjusted associations**	
	OR	95% CI	OR	95% CI
Priority groups				
Healthcare workers	Ref		Ref	
Medically vulnerable and elderly – comorbidity and/or >75 y	**0.48**	**0.43, 0.54**	**0.43**	**0.37, 0.48**
Non-healthcare essential workers	**0.21**	**0.18, 0.25**	**0.28**	**0.23, 0.34**
General population	**0.25**	**0.22, 0.28**	**0.32**	**0.28, 0.37**
Age				
18-24	**0.14**	**0.12, 0.17**	**0.18**	**0.15, 0.22**
25-44	**0.19**	**0.17, 0.21**	**0.21**	**0.18, 0.24**
45-64	**0.28**	**0.25, 0.31**	**0.30**	**0.27, 0.34**
65-74	**0.65**	**0.57, 0.74**	**0.63**	**0.56, 0.71**
75+	Ref		Ref	
Sex				
Female	Ref		Ref	
Male	**0.72**	**0.68, 0.77**	**0.82**	**0.77, 0.88**
Race/ethnicity				
Non-Hispanic White	Ref		Ref	
Asian	1.01	0.86, 1.18	1.16	0.96, 1.40
Non-Hispanic Black	**0.63**	**0.56, 0.69**	**0.78**	**0.69, 0.88**
Hispanic	**0.61**	**0.55, 0.67**	1.05	0.92, 1.19
American Indian and Native Alaskan	0.85	0.61, 1.18	**1.47**	**1.04, 2.07**
Other	**0.62**	**0.50, 0.79**	0.84	0.66, 1.09
Combined family Income USD				
0-29,999	**0.70**	**0.64, 0.76**	**0.83**	**0.75, 0.93**
30,000-59,999	**0.69**	**0.64, 0.75**	**0.76**	**0.69, 0.83**
60,000-99,999	**0.76**	**0.70, 0.82**	**0.80**	**0.74, 0.88**
100,000+	Ref		Ref	
Educational attainment				
4 years college +	Ref		Ref	
High school or less	**0.58**	**0.54, 0.62**	**0.75**	**0.68, 0.82**
< 4 years college	**0.63**	**0.58, 0.68**	**0.71**	**0.65, 0.78**
Region				
Northeast	Ref		Ref	
South	**0.75**	**0.68, 0.84**	0.90	0.80, 1.01
Midwest	**0.88**	**0.78, 0.98**	1.01	0.89, 1.13
West	**0.84**	**0.74, 0.95**	0.96	0.85, 1.09

US birth				
Born in US	Ref		Ref	
Not born in US	**0.81**	**0.74, 0.87**	0.91	0.80, 1.04
Transportation				
No Healthcare delays due to transportation	Ref		Ref	
Healthcare delays due to transportation	0.90	0.73, 1.11	1.05	0.84, 1.32
Healthcare information				
Researched health information on the internet	Ref		Ref	
Did not research health information on the internet	**0.82**	**0.77, 0.87**	**0.84**	**0.78, 0.91**
Smoking behavior				
Never smoker	Ref		Ref	
Former smoker	**1.38**	**1.28, 1.50**	1.05	0.97, 1.15
Current smoker	**0.53**	**0.48, 0.58**	**0.63**	**0.57, 0.70**
Health insurance				
Health insurance	Ref		Ref	
No health Insurance	**0.21**	**0.18, 0.25**	**0.36**	**0.31, 0.42**

* Crude associations between flu vaccine uptake and priority groups, and covariates of interest.
**Adjusted associations between vaccine uptake and priority groups, and covariates of interest. All variables were adjusted simultaneously.
Bold: Statistically significant at alpha=0.05.

Figure 1. Prior flu vaccine uptake by COVID-19 vaccination priority group, NHIS 2018



Comparison of flu vaccine uptake (%) for all US adults, healthcare workers, individuals who are medically vulnerable, essential workers, and the general population. Error bars represent 95% CI.

Supplemental Information

Northeast- New England Division (ME, NH, VT, MA, RI, and CT) and Middle Atlantic Division (NY, NJ, and PA)

North Central/Midwest: East North Central Division (MI, OH, IN, IL, WI) and West North Central Division (MN, IA, MO, ND, SD, KS, and NE)

South: South Atlantic Division (DE, MD, DC, VA, WV, NC, SC, GA, and FL), East South Central Division (KY, TN, MS, and AL), and West South Central Division (TX, AR, OK, and LA)

West: Pacific Division (WA, AK, OR, CA, and HI) and Mountain Division (MT, ID, WY, CO, NM, AZ, UT, and NV)

Healthcare workers includes critical healthcare workers (Health diagnosing and treating practitioners, health technologists and technicians, other healthcare practitioners and technical occupations, nursing, psychiatric, and home health aides, occupational and physical therapist assistants and aides, other healthcare support occupations, funeral service workers) as per ACIP.

Medically vulnerable individuals include adults aged 65 years and older, and individuals aged 18-64 with one or more of the following comorbidities: cancer, type 2 diabetes, chronic kidney disease, chronic obstructive pulmonary disease, obesity (body mass index>=30), heart condition, asthma, stroke, hypertension, dementia, liver disease as per ACIP.

Non-healthcare essential workers includes first-line managers/supervisors, protective service workers, firefighting and prevention workers, law enforcement workers, other protective service workers, animal care and service workers, primary, secondary, and special education school teachers, post-secondary teachers, other teachers and instructors, retail sales workers, supervisors, farming, fishing, and forestry workers, agricultural workers, fishing and hunting workers, forest, conservation and logging workers, supervisors of installation, maintenance, and repair workers, electrical and electronic equipment mechanics, installers, and repairers, supervisors, production workers, food processing workers, metal workers and plastic workers, assemblers and fabricators, other production occupations, motor vehicle operators, electrical and electronic equipment mechanics, installers and repairers, and animal care and service workers).

General population includes workers not previously covered in prior categories (Chief executives; general and operations managers; legislators, advertising, marketing, promotions, public relations, and sales managers, operations specialties managers, other management occupations, business operations specialists, financial specialists, mathematical science occupations, architects, surveyors, and cartographers, engineers, drafters, engineering, and mapping technicians, life scientists, physical scientists, social scientists and related workers, Life, physical, and social science technicians, religious workers, counselors, social workers, and other community and social service specialists, lawyers, judges, and related workers, legal support workers, librarians, curators, and archivists, other education, training, and library occupations, media and communication workers, media and communication equipment workers, supervisors, food preparation, and serving workers, cooks and food preparation workers, food and beverage serving workers, other food preparation and serving related workers, woodworkers,

supervisors, building and grounds cleaning and maintenance workers, building cleaning and pest control workers, grounds maintenance workers, supervisors, personal care and service workers, transportation and logistics, tourism, and lodging attendants, supervisors, sales workers, retail sales workers, sale representative, services, sale representative, wholesale and manufacturing, other sales and related workers, supervisors, office and administrative workers, communications and IT equipment operators, financial clerks, information and record clerks, material recording, scheduling, dispatching, and distributing workers, secretaries and administrative assistants, other office and administrative support workers, forest, conservation, and logging workers, supervisors, construction and extraction workers, construction trades workers, helpers, construction trades, other construction and related workers, extraction workers, supervisors of installation, maintenance, and repair workers, vehicle and mobile equipment mechanics, installers, and repairers, other installation, maintenance, and repair occupations, printing workers, textile, apparel, and furnishing workers, plant and system operators, supervisors, transportation and material moving workers, air Transportation and logistics workers, rail transportation and logistics workers, water transportation and logistics workers, other transportation and logistics workers, material moving workers).

Conclusions

This work made two major contributions to the literature. First, nationally representative data were used to first estimate the racial and ethnic, age, sex, and regional distribution of non-institutionalized populations prioritized for COVID-19 vaccination, providing national benchmarks for comparison between the demographic composition of those eligible for vaccination and those who received the vaccine in the early US vaccination campaign. Second, we found that the medically vulnerable, non-healthcare essential workers, and the general population were all less likely to get an annual flu vaccine compared to healthcare workers in the United States. Relatedly, we found that socio-demographic characteristics such as being Black, young, male, less educated, earning less than $100,000, having no health insurance, and not researching health information on the internet were all associated with lower flu vaccine uptake. Based on these national experiences with the flu vaccine, our analyses highlights potential groups who may experience barriers to receiving the COVID-19 vaccine.

Several factors might be at play for lack of uptake, such as perceived notions of vaccines being dangerous or not working as advertised, lack of knowledge of the benefits of vaccines, accessibility, and mistrust in the health system. Evidence-based and tailored communication strategies and vaccination delivery policies must be implemented to directly address barriers to COVID-19 vaccine uptake among adult populations with a history of lower coverage of recommended vaccinations in this country.

References

1. Dooling K. 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. doi:10.15585/mmwr.mm695152e2

2. Episode #1 - Herd immunity. Accessed March 23, 2021. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/media-resources/science-in-5/episode-1

3. Hawkins D. Differential occupational risk for COVID-19 and other infection exposure according to race and ethnicity. *Am J Ind Med*. Published online June 15, 2020. doi:10.1002/ajim.23145

4. CDC. Community, Work, and School. Centers for Disease Control and Prevention. Published February 11, 2020. Accessed April 20, 2021. https://www.cdc.gov/coronavirus/2019-ncov/community/health-equity/race-ethnicity.html

5. Across The South, COVID-19 Vaccine Sites Missing From Black And Hispanic Neighborhoods. NPR.org. Accessed April 18, 2021. https://www.npr.org/2021/02/05/962946721/across-the-south-covid-19-vaccine-sites-missing-from-black-and-hispanic-neighbor

6. Muñana C, 2020. KFF COVID-19 Vaccine Monitor: December 2020. KFF. Published December 15, 2020. Accessed April 20, 2021. https://www.kff.org/coronavirus-covid-19/report/kff-covid-19-vaccine-monitor-december-2020/

7. Khubchandani J, Sharma S, Price JH, Wiblishauser MJ, Sharma M, Webb FJ. COVID-19 Vaccination Hesitancy in the United States: A Rapid National Assessment. *J Community Health*. Published online January 3, 2021:1-8. doi:10.1007/s10900-020-00958-x

8. Education Is Now a Bigger Factor Than Race in Desire for COVID-19 Vaccine. USC Schaeffer. Published March 3, 2021. Accessed April 21, 2021. https://healthpolicy.usc.edu/evidence-base/education-is-now-a-bigger-factor-than-race-in-desire-for-covid-19-vaccine/

9. Malik AA, McFadden SM, Elharake J, Omer SB. Determinants of COVID-19 vaccine acceptance in the US. *EClinicalMedicine*. 2020;26:100495. doi:10.1016/j.eclinm.2020.100495

10. Kreps S, Prasad S, Brownstein JS, et al. Factors Associated With US Adults' Likelihood of Accepting COVID-19 Vaccination. *JAMA Network Open*. 2020;3(10):e2025594-e2025594. doi:10.1001/jamanetworkopen.2020.25594

11. Ventola CL. Immunization in the United States: Recommendations, Barriers, and Measures to Improve Compliance. *P T*. 2016;41(8):492-506.

12. Postma MJ, Carroll S, Brandão A. The societal role of lifelong vaccination. *J Mark Access Health Policy*. 2015;3. doi:10.3402/jmahp.v3.26962

13. Roll Up Your Sleeves: Adult Immunizations. Pharmacy Times. Accessed April 16, 2021. https://www.pharmacytimes.com/view/roll-up-your-sleeves-adult-immunizations

14. Anderson EL. Recommended Solutions to the Barriers to Immunization in Children and Adults. *Mo Med*. 2014;111(4):344-348.

15. Esposito S, Durando P, Bosis S, Ansaldi F, Tagliabue C, Icardi G. Vaccine-preventable diseases: From paediatric to adult targets. *European Journal of Internal Medicine*. 2014;25(3):203-212. doi:10.1016/j.ejim.2013.12.004

16. Schaffer DeRoo S, Pudalov NJ, Fu LY. Planning for a COVID-19 Vaccination Program. *JAMA*. 2020;323(24):2458-2459. doi:10.1001/jama.2020.8711

17. Cannon LM and Y. How to build more equitable vaccine distribution technology. Brookings. Published February 23, 2021. Accessed April 21, 2021. https://www.brookings.edu/techstream/how-to-build-more-equitable-vaccine-distribution-technology/

18. Lu P, O'Halloran A, Williams WW, Lindley MC, Farrall S, Bridges CB. Racial and ethnic disparities in vaccination coverage among adult populations. *Am J Prev Med*. 2015;49(6 Suppl 4):S412-S425. doi:10.1016/j.amepre.2015.03.005

19. Ferdinand KC. Overcoming Barriers to COVID-19 Vaccination in African Americans: The Need for Cultural Humility. *Am J Public Health*. 2021;111(4):586-588. doi:10.2105/AJPH.2020.306135

20. Momplaisir F, Haynes N, Nkwihoreze H, Nelson M, Werner RM, Jemmott J. Understanding Drivers of COVID-19 Vaccine Hesitancy Among Blacks. *Clinical Infectious Diseases*. 2021;(ciab102). doi:10.1093/cid/ciab102

21. Largent EA, Persad G, Sangenito S, Glickman A, Boyle C, Emanuel EJ. US Public Attitudes Toward COVID-19 Vaccine Mandates. *JAMA Netw Open*. 2020;3(12):e2033324. doi:10.1001/jamanetworkopen.2020.33324

22. Callaghan T, Moghtaderi A, Lueck JA, et al. *Correlates and Disparities of COVID-19 Vaccine Hesitancy*. Social Science Research Network; 2020. doi:10.2139/ssrn.3667971

23. Jean-Jacques M, Bauchner H. Vaccine Distribution—Equity Left Behind? *JAMA*. 2021;325(9):829. doi:10.1001/jama.2021.1205

24. Romer D, Jamieson KH. Conspiracy theories as barriers to controlling the spread of COVID-19 in the U.S. *Social Science & Medicine*. 2020;263:113356. doi:10.1016/j.socscimed.2020.113356

25. Wood S, Schulman K. Beyond Politics — Promoting Covid-19 Vaccination in the United States. *New England Journal of Medicine*. 2021;384(7):e23. doi:10.1056/NEJMms2033790

26. Fisk RJ. Barriers to vaccination for coronavirus disease 2019 (COVID-19) control: experience from the United States. *Glob Health J*. 2021;5(1):51-55. doi:10.1016/j.glohj.2021.02.005

27. Fu LY, Haimowitz R, Thompson D. Community members trusted by African American parents for vaccine advice. *Hum Vaccin Immunother*. 2019;15(7-8):1715-1722. doi:10.1080/21645515.2019.1581553

28. Bode L, Vraga EK. See Something, Say Something: Correction of Global Health Misinformation on Social Media. *Health Communication*. 2018;33(9):1131-1140. doi:10.1080/10410236.2017.1331312

29. CDC. Cases, Data, and Surveillance. Centers for Disease Control and Prevention. Published February 11, 2020. Accessed April 18, 2021. https://www.cdc.gov/coronavirus/2019-ncov/covid-data/investigations-discovery/hospitalization-death-by-race-ethnicity.html

30. Painter EM. Demographic Characteristics of Persons Vaccinated During the First Month of the COVID-19 Vaccination Program — United States, December 14, 2020–January 14, 2021. *MMWR Morb Mortal Wkly Rep*. 2021;70. doi:10.15585/mmwr.mm7005e1

31. CDC. COVID Data Tracker. Centers for Disease Control and Prevention. Published March 28, 2020. Accessed March 23, 2021. https://covid.cdc.gov/covid-data-tracker

32. Pham O, Alam R, Apr 14 NPP, 2021. Latest Data on COVID-19 Vaccinations Race/Ethnicity. KFF. Published April 14, 2021. Accessed April 18, 2021. https://www.kff.org/coronavirus-covid-19/issue-brief/latest-data-on-covid-19-vaccinations-race-ethnicity/

33. CDC. COVID Data Tracker. Centers for Disease Control and Prevention. Published March 28, 2020. Accessed April 6, 2021. https://covid.cdc.gov/covid-data-tracker

34. Dooling K. 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. doi:10.15585/mmwr.mm695152e2

35. COVID-19 Vaccine Key to Reaching 'Herd Immunity.' Accessed March 30, 2021. https://www.muhealth.org/our-stories/covid-19-vaccine-key-reaching-herd-immunity

36. States ranked by percentage of COVID-19 vaccines administered: April 16. Accessed April 16, 2021. https://www.beckershospitalreview.com/public-health/states-ranked-by-percentage-of-covid-19-vaccines-administered.html

37. IPUMS NHIS. Accessed March 10, 2021. https://nhis.ipums.org/nhis/userNotes_variance.shtml

38. State COVID-19 Vaccine Priority Populations. KFF. Published March 29, 2021. Accessed March 30, 2021. https://www.kff.org/other/state-indicator/state-covid-19-vaccine-priority-populations/

39. Meissner HC. Why is herd immunity so important? *AAP News*. 2015;36(5):14-14. doi:10.1542/aapnews.2015365-14

40. Callaghan T, Moghtaderi A, Lueck JA, et al. Correlates and disparities of intention to vaccinate against COVID-19. *Soc Sci Med*. 2021;272:113638. doi:10.1016/j.socscimed.2020.113638

41. Hawkins D. Differential occupational risk for COVID-19 and other infection exposure according to race and ethnicity. *Am J Ind Med*. 2020;63(9):817-820. doi:10.1002/ajim.23145