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Nafis Khan Date

Characterizing Low Vaccination Coverage of COVID-19 in Georgia in 2021: A Quantitative Study

By

Nafis Khan

Master of Public Health

Epidemiology

Shivani A. Patel

Committee Chair

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By

Nafis Khan

Bachelor of Science

Pennsylvania State University

2018

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

An abstract of

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Abstract

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By Nafis Khan

Background: Unequal coverage of the COVID-19 vaccine has been an obstacle in controlling the COVID-19 pandemic in the state of Georgia. Using the Georgia Department of Public Health's COVID-19 surveillance data we assessed the association of age, race, ethnicity, sex, and rurality with vaccination status and reasons for being unvaccinated among adults with confirmed COVID-19 within Georgia.

Methods: Monthly vaccination status among confirmed cases was computed over 2021. We examined the demographic composition of vaccinated and unvaccinated cases and estimated associations between demographic characteristics and being unvaccinated using logistic regression. Nine reasons for being unvaccinated against COVID-19 were grouped into 3 categories: accessibility issues (inaccessible, inconvenient, expensive); confliction of beliefs (religious exemption, philosophical objection, parental/patient refusal); and medical/other reasons (medical contraindication, concurrent illness, forgot to vaccinate). We computed bivariate correlations among reasons for being unvaccinated and conducted principal components analysis (PCA) to identify whether the 9 responses could be reduced to a smaller set of factors. We conducted logistic regressions to examine associations between demographic factors and the 3 categories of vaccine hesitancy separately.

Results: Analyzing the 695,472 confirmed cases showed unvaccinated outnumbered vaccinated 3:1 during 2021. Younger Georgians (18-49) had the highest likelihood of being unvaccinated confirmed cases, as did Black and American Indian race groups. 'No access' was the most cited reason for being unvaccinated (33.53%), followed by 'philosophical objection' (8.75%) and 'parental/patient refusal' (8.57%). There was a low degree of correlation among the reasons for being unvaccinated, with the first and second principal components explaining 14.21% and 12.16% of the variation in reasons for being unvaccinated, respectively. There were significant, positive associations of being middle age (50-64) and being Asian with accessibility issues, and inverse associations of being female and living in non-metro areas with accessibility.

Conclusion: In 2021, accessibility was the most common reason for being unvaccinated among confirmed COVID-19 cases reported to the Georgia Department of Public Health. The analysis provides retrospective insight into commonly cited reasons for being unvaccinated as well as patterns of hesitancy among demographic groups. This may be used to design better interventions focused on improving vaccination uptake across the state.

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Introduction

By the end of 2021, the COVID-19 pandemic had made a significant global impact infecting over 286 million people worldwide with the United States (US) making up about 54 million of those cases (World Health Organization, 2022). The first year of the pandemic was contained by strict international lockdowns with the hope that a vaccine would allow for a return to normal life. Despite widespread availability of the COVID-19 vaccine by April 2021, the United States had only managed to fully vaccinate about 62% of the population by the end of 2021 (Hannah Ritchie *et al.*, 2020). During the first four months of vaccine distribution (January 2021 to April 2021), 46% of the US population received at least one dose of their COVID-19 vaccination (Hannah Ritchie *et al.*, 2020). It is necessary to increase vaccination rates in the US to control the pandemic. To reach the remaining groups of unvaccinated people it first needs to be known why they are unvaccinated and what they need to become vaccinated. However, there many factors that contribute to a person's health decision-making and reasons why a person may not get a vaccine. Understanding the clustering of social, health, and demographic factors may generate descriptions or phenotypes for those who have refused the COVID-19 vaccine or have been vaccine hesitant. Exploring these relationships and identifying these common trends will help to define these phenotypes more clearly.

Several factors can play a role in low vaccine uptake. Reasons for not being vaccinated can be broadly divided into three categories: medical contraindications, accessibility issues, and confliction of beliefs/vaccine hesitancy. Medical contraindications include concurrent illness and comorbidities. Accessibility may be limited for people with mobility issues or disabilities, or it could be a financial burden to go through the vaccination process. As for vaccine hesitancy, defined as a "delay in acceptance or refusal of vaccination despite availability of vaccination

services" it could be due to a conflict with a combination of moral, religious, or political beliefs given that "vaccine hesitancy is complex and context specific" (MacDonald, 2015). For people living in rural locations, mass vaccination sites in large cities may be the only place where vaccines are offered, requiring reliable transportation which is not always feasible. Vaccine skepticism is also a contributor to low vaccination rates, but issues with low COVID-19 vaccine turnout are not a monolith; more than one reason for being unvaccinated can be at play for many people. Understanding the contributions to the low vaccine turnout help to understand what the issues are, who they affect, and where they are most prevalent.

The purpose of this study is to evaluate the reasons why individuals with confirmed COVID-19 disease were not vaccinated at the time of contracting virus. The research seeks to understand overarching themes of vaccine hesitancy and its distribution. To gain control of the COVID-19 pandemic, the US needs to improve vaccination rates, and this information plays a large part in understanding the trends and prevalence of vaccine hesitancy. There is also application to future pandemics to assess what groups are most at-risk from obstacles to vaccine hesitancy. The audience for this study is healthcare providers and decision makers who will be better able to assess allocation of vaccine resources and planned interventions with the help of this analysis.

Extended Literature Review

What is known about vaccine hesitancy?

The promotion of vaccine hesitancy ideology has helped to prolong the COVID-19 pandemic by perpetuating the belief that vaccines are harmful. While some concerns towards vaccination practices are valid and addressed, the spread of vaccine misinformation has impeded the administration of the COVID-19 vaccination. The World Health Organization states that vaccine hesitancy is a behavior influenced by several factors including confidence in the vaccine product, concerns about the risk of disease, and convenience to access the vaccine (Cornelia Betsch, Constanze Rossmann, and Katrine Bach Habersaat, 2017). Those described as vaccine hesitant make up a heterogenous group with differing views on vaccine acceptance.

Vaccine hesitancy has been a phenomenon long before the COVID-19 pandemic. There have been proponents against vaccinations since the introduction of the first vaccine: the smallpox vaccination. In 1796 Edward Jenner created the smallpox vaccination to control the pandemic that had been pillaging England. In 1840, the United Kingdom instilled an act to make smallpox vaccinations mandatory and by 1869 the Leister anti-vaccination league was created to oppose this mandate (Dubé, Vivion and MacDonald, 2015). This pattern of the introduction of a vaccine followed by opposition to that vaccine has been perpetuated multiple times since. A major moment for the anti-vaccination movement came when Andrew Wakefield reported findings that linked the MMR vaccine to increased risk of autism development in 1998. His study and results were retracted because of conflicts of interest and scientific misconduct, but it is still largely accepted by anti-vaccination proponents as they argue about the dangers of vaccinations (Flaherty, 2011).

Given the success of many different vaccines, there is the thought that vaccines perpetuate vaccine hesitancy as "fewer people witness the consequences of forgoing vaccines" (McAteer, Yildirim and Chahroudi, 2020). With overall prevalence of a disease decreasing due to vaccination the perceived threat also decreases and the focus comes to adverse reactions to the vaccines. As a result, certain vaccine preventable diseases have shown increased incidence such as measles which in had 1282 confirmed cases in 2019 alone, the highest it has been since 1992 (McAteer, Yildirim and Chahroudi, 2020). One glaring issue with addressing vaccine hesitancy is that there have been few studies and there is little overall understanding of the concept. Most instances of vaccine hesitancy have been anecdotal and lack any substantial research backing the phenomenon. Following the measles outbreak of 2019, the United States government decided to dedicate resources to address the ideologies behind vaccine hesitancy in the form of the Vaccine Awareness Campaign to Champion Immunization Nationally and Enhance Safety (VACCINES) Act. Moving forward with this campaign will seek to characterize the rationales behind vaccine hesitancy (McAteer, Yildirim and Chahroudi, 2020).

What are the characterizations of vaccine hesitancy?

Initial studies on vaccine hesitancy have sought to identify trends in the groups most likely to be vaccine hesitant. The literature review carried out by Troiano and Nardi highlight characteristics related to vaccine hesitancy (Troiano and Nardi, 2021). The review found trends in race, socio-economic status, religiosity, politics, among other factors. While their list is not exhaustive it does highlight valuable topic worthy of further exploration:

> **Race:** Throughout the pandemic, studies have shown that minority groups, particularly black communities living in poverty, have been disproportionately affected by COVID-19. A study of "131 predominantly (African American) counties show a COVID-19

infection rate of 137.5 per 100,000, and a death rate of 6.3 per 100,000 which is three times higher (and six times higher respectively) than non-Hispanic white counties" (Alcendor, 2020). These disparities likely occur due to health inequities such as inability to access healthcare treatment when needed, lack of access to healthcare providers due to scheduling or transportation issues, or limited access to medical attention/treatment. These trends of inequal healthcare distribution among minorities have carried over to distribution of the COVID-19 vaccinations. By April of 2021 "COVID-19 vaccination rates in White people were almost twice as high as rates in Hispanic and Black people" based on available data from 43 US states (Khan *et al.*, 2021). In addition to lack of access, lack of trust with government entities by minorities and people of color (POC) has perpetuated vaccine hesitancy and that has been evident with the COVID-19 vaccine. Instances of inhumane treatment to minority groups by the US have been well documented. The Tuskegee syphilis experiment where black study participants had syphilis treatments withheld over the course of decades is a common example (*Tuskegee Study - Frequently Asked Questions - CDC - NCHHSTP*, 2021). The lasting impact of this study has been strained relationships between healthcare providers and POC communities. The damage has been evident in the lower vaccination rates among POC and the subsequent challenge to achieve a high enough vaccination rate in the US to end the COVID-19 pandemic.

Socioeconomic Status (SES): The impact of socioeconomic status on vaccine hesitancy is not so conclusive. Depending on the location, the likelihood of vaccine hesitancy may vary with SES. While some regions may show lower SES to be more vaccine hesitant, other regions may have higher SES demographics being more vaccine hesitant. In a

literature review conducted by Hudson and Montelpare assessing predictors of vaccine hesitancy, vaccine hesitant American families were “more likely to reside in communities with higher household incomes than families who did not refuse vaccination” (Hudson and Montelpare, 2021). However, the same review stated that low-income, post-partum mothers were “associated with less trustful attitudes toward vaccination”. While both low SES and high SES groups may perpetuate vaccine hesitancy sentiment, the rationale for each group likely varies. A common reasoning used to describe lower SES household vaccine hesitancy is healthcare system mistrust like the issues mentioned for POC; the historic mistreatment and health inequality overlaps with those of lower SES. Vaccine concerns for lower SES individuals regard the “safety and necessity of vaccines as compared to those with higher socio-economic status” (Kumar *et al.*, 2016). Necessity here is determined by the ability to participate in everyday activities if the vaccine is not taken. Additionally, safety here refers to whether adverse effects of intervention have been fully explored and if the threat outweighs the benefit. However, issues contributing to higher SES household vaccine hesitancy are less clear. Distrust may also play a role for people with higher SES, but lifestyle choices focused on “clean living values” emphasizing “purity and natural immunity” could also be a factor (Hudson and Montelpare, 2021).

Education: Among local and state specific studies education levels also shows some impact on the likelihood of vaccine hesitancy. An Arkansas study was conducted to gauge the response and willingness to take the COVID-19 vaccine. The study considered clustering and other factors that may impact vaccine hesitancy. Arkansas is one of the larger agrarian states of the US by percentage “which often lack adequate health care

resources and primary care providers". As a result of lower access to healthcare, Arkansas has the third highest at-high-risk population for serious COVID-19 cases at 46.5% of the population (Willis *et al.*, 2021).The lack of access to healthcare and higher risk for poor health outcomes contributes to lower health literacy propagating vaccine hesitancy. In the study, 32.17% of respondents who had reported receiving "some college or a technical degree" were hesitant to getting the COVID-19 vaccine which was the highest prevalence across all the educational categories (high school diploma or less, some college or technical degree, and 4-year college degree or more). In fact, the 'some college' category was 1.67 times as likely to be vaccine hesitant compared to an individual from the 4-year degree category (High school category not significantly different from the 4-year college baseline). Studies have shown a "distrust of medical professionals amongst communities with less formal education" leaving a lot of room for hesitancy towards vaccines. Compared to higher education groups, health literacy is lower and communicating the benefits of vaccination may be difficult (Kumar *et al.*, 2016).

Political preference: Within the United States, the topic of how to handle the COVID-19 pandemic, vaccines, and vaccine mandates has become a partisan issue. The Democratic party's focus regarding the COVID-19 pandemic has been on "the threat of the virus and the potential benefits of broad restrictions – namely, lower cases, transmission, and deaths". In contrast the Republican Party's focus is on the "cost of broad restrictions—such as job loss, psychological harm, and delayed treatment of non-COVID-19 related illnesses" (Collins, Mandel and Schywiola, 2021). As the pandemic has progressed, these ideological differences have grown deeper and the partisan nature of "antivaccine

attitudes… has become an important signifier of membership in a social group" (Tram *et al.*, 2021). Attempts to market the vaccine as safe and effective to skeptics may be unsuccessful as adherence to political or social group undermines the ongoing vaccination promotion efforts. When accounting for different demographic and social factors, however, these political stratifications on vaccination hesitancy become more complex. Political leanings seemed to determine vaccination opinion more often in some white Americans than black Americans, and in fact "hesitancy among black Americans was less correlated with state-level political context" (Tram *et al.*, 2021). Using politics as a measure of the likelihood of someone becoming vaccinated offers a lot of room for bias from factors such as environment, SES, or race. However, understanding the impact of politics on vaccine hesitancy will help in tailoring interventions to meet the right people.

Age: When discussing age regarding vaccine hesitancy, understanding the history of public health can help to understand the rationale behind different age groups. Older generations that had to suffer through disease such as polio understand the damage uncontrolled disease can bring upon a society. They have also seen how the introduction of vaccines has greatly improved the quality of life and mitigated fears from disease. It would be natural to think that as society and science has progressed, that belief in the science has also improved. However, skepticism towards vaccination has only increased. The struggle to achieve complete vaccine coverage may be age related as "many countries have experienced higher vaccine hesitancy among younger generations" (Khan, Watanapongvanich and Kadoya, 2021). Reasons why belief in vaccination has been diminishing include an inability to perceive the threat of the diseases vaccines prevent.

> Tuberculosis, pertussis, measles, mumps, and rubella have all been brought to a manageable level in the United States. The diseases used to be contributors to high infant and child mortality, but with the introduction of their vaccines their threat has greatly diminished. A prevailing belief in the anti-vax community is that the risks of vaccination outweigh the benefits. The influence of age on anti-vaccination sentiment may align with the timeline of these diseases and historical impact they serve. While there are still other factors involved, vaccine hesitancy may skew towards younger age demographics.

Where does vaccine hesitancy occur?

It can be unclear what the overall prevalence of vaccine hesitancy is within the United States. There are general differences in vaccination coverage between the north and the south however, there is greater complexity when it comes to determining the distribution of vaccine hesitancy by state and region. The distributions of vaccinations in rural and urban regions may play a role in this discrepancy given that rural communities are more prevalent in the south with many major cities being in the Northeast or the West. In an analysis on US county-level data urban vaccination coverage was overall 6.8% greater than rural vaccination coverage. Coupled with the fact that "rural communities often have a higher proportion of residents who lack health care, live with comorbidities or disabilities, are aged ≥ 65 years, and have limited access to health care facilities with intensive care capabilities" this creates an environment of low health literacy and higher vaccine hesitancy (Murthy BP, Sterrett N, Weller D, et al., 2021). Occupation may also play a role in influencing vaccine hesitancy. Given the great amounts of time people spend at their jobs, there may be pro or anti-vaccination rhetoric spread in these areas. Vaccine mandates may influence an increase in vaccinations while those willing to abstain from being vaccinated may join with others to prevent any mandates. Shutdowns, transitions to work from home

(WFH), and workplaces that allow for distance and isolation may also influence a desire to get vaccinated as some people may not see the need if they are not in high contact/risk areas. In a study representative of the US working class, the highest levels of vaccine hesitancy occurred in construction, maintenance, farming, and transportation services where the majority of the hesitancy participants stated a strong hesitancy to the vaccine and mistrust in the government (King *et al.*, 2021). However, there were still relatively high reports of hesitancy in fields of close contact with COVID-19 patients. Among health care professionals such as nurses, hesitancy was reported above 15% while "(study) participants working outside the home reported COVID-19 vaccine hesitancy at more than twice the rate of those working from home" (King *et al.*, 2021). Since most work from home jobs were previously held in an office, there may be an association between vaccine hesitancy and jobs that require manual labor where being on site is a requirement.

How has vaccine hesitancy been perpetuated?

Many fears against vaccines are warranted; not everyone understands the intricacies of vaccine development. Additionally, there are health risks that can occur following vaccination. As mentioned, there is a history of the US government abusing its trust with various groups of people in the name of science. With that being said, for the vast majority, the risk is miniscule, and the benefits are vast. There is a concerted effort for transparency when discussing vaccination and the anti-vaccination sentiment built on misinformation is a disservice to those who are unsure about the risks and benefits of vaccination. This growing body of work against vaccinations has played a significant role in vaccine hesitancy regarding the COVID-19 vaccination. While proactive measures have been employed such as "pre-emptive cognitive inoculation techniques and pre-bunking techniques" against misinformation around the COVID-

19 vaccination, the spread of misinformation is still an issue. Despite these measures, those who use “social media/internet as a primary source of COVID-19 related information were more prone to increased vaccine hesitancy” (Aw *et al.*, 2021). With the introduction of the internet, it has become easier to find groups that share one’s similar thinking. Social media has only enhanced this ability to connect allowing people to build a community with those who share their own thoughts. Regardless of the pre-emptive measures taken, if they are not meeting their target audience then they are unable to serve their purpose.

Research objectives

This study seeks to characterize phenotypes of vaccine hesitancy among confirmed cases of COVID-19 recorded by the Georgia department of Public Health (GDPH) to identify any correlations that can help in improving interventions to increase low COVID-19 vaccination rates. Through our analysis we sought to describe the distribution of vaccination status among confirmed cases of COVID-19 in Georgia in 2021, assess demographic differences between vaccinated and unvaccinated cases, categorized the reasons why confirmed cases did not receive the COVID-19 vaccine, and evaluate any correlations between demographic information and the reasons why confirmed cases had not received the vaccine. We draw on data from the GDPH COVID-19 surveillance database. This database contains information and responses from all patients under investigation for COVID-19 and include vaccination status, reasons why individuals did not take the vaccine, demographic information, and location. Being able to identify characteristics of people who have not received the vaccine is the first step to understanding the many reasons for not being vaccinated.

Methods

Data sources

The GDPH has been collecting data on the transmission of COVID-19 since the start of the pandemic. Every health system in the state of Georgia affiliated with the GDPH has been reporting the number of probable and confirmed COVID-19 cases throughout the pandemic as well as any background or demographic information available on the cases. We focused on confirmed adult (18+) COVID-19 cases (Patient Under Investigation: PUI) in Georgia from January 2021 to December 2021 for our analysis. A confirmed case is defined as "an individual with a positive molecular (PCR (Polymerase Chain Reaction)) test" (Georgia Department of Public Health, 2021). There were 2,355,032 potential cases for 2021. 695,472 of those cases met the inclusion criteria and were included in the study.

Outcomes

The outcomes we used in our analysis included self-reported vaccination status among confirmed cases (binary indicator: vaccinated or unvaccinated) and reasons why vaccination was refused. The reasons for not receiving vaccinations were collected as a fully-structured multiple select questionnaire. There were 9 response options available to respondents: No Access, Inconvenience, Too Expensive, Religious Exemption, Philosophical, Objection, Parental/Personal Refusal, Forgot to Vaccinate, Concurrent Illness, and Medical Contraindication. The categories were not mutually exclusive from one another, and a respondent was able to select multiple reasons for not getting vaccinated. In addition, the 9 reasons given why COVID-19 vaccine was refused were consolidated into 3 broader categories: Accessibility (No Access, Inconvenience, Too Expensive); Beliefs (Religious Exemption,

Philosophical Objection, Parental/Personal Refusal); and Medical Reasons (Forgot to Vaccinate, Concurrent Illness, Medical Contraindication).

Demographic characteristics

Age was categorized into three groups: 18-49 year old, 50-64 years old, and 65+ years old. Race was categorized as White, Black or African American, Asian, American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander. Ethnicity was categorized as Hispanic/Latino and Not Hispanic/Latino. Sex was categorized as Male and Female. Rurality was categorized as Metro and Non-metro. Rurality was used to identify if the county where PUI was at time of initial report was classified as a metropolitan area or a non-metropolitan area. Rurality was determined based on the GDPH rural-urban continuum codes from 2013. A metropolitan county for our study was defined as being in a metro area with any size population or being an urban population with a size of 2,500 to 20,000 people. A non-metropolitan area was defined as having a completely rural population or an urban population with a size less than 2,500. All demographic factors were analyzed as categorical variables in models.

Statistical analysis

SAS 9.4 was used for all analyses (*SAS/ACCESS® 9.4 Interface to ADABAS*, 2013).

The distribution of vaccination status (vaccinated vs unvaccinated) was described among confirmed COVID-19 cases by month. Total count of cases, count of vaccinated cases, count of unvaccinated cases, and the proportions of vaccinated and unvaccinated cases compared to total cases from January 2021 to December 2021 were given to show change of case distribution over time.

The distribution of total number of COVID-19 cases, demographic composition (age, race, ethnicity, sex, and rurality), and completeness of surveillance data for vaccinated and unvaccinated cases, separately, was also described.

Logistic regression was used to determine associations between demographic variables and vaccination status. The odds ratios were estimated for each demographic variables (age, race, ethnicity, sex, rurality) before and after adjusting for the influence of the other variables to show if any group within each stratum was significantly impacted by the demographic variables.

The percentage of individuals endorsing each reason for not receiving the COVID-19 vaccination was calculated. Each category was counted separately to understand what reasons were most and least frequently stated.

We examined whether there were any clusters of response patterns in reasons for not being vaccinated. First, we estimated the correlation among all potential reasons why individuals were not vaccinated using a Pearson correlation. Correlations were computed to understand if there were any patterns of clustering of reasons for not being vaccinated in the unweighted data. Second, we applied Principal Components Analysis (PCA) to assess whether the 9 reasons could be reduced to a smaller set of response clusters. PCA reweights the values of reasons why the COVID-19 vaccine was not received to display the potential clustering of reasons in a manner than maximizes the variation across components (*Econometrics Academy - Principal Component Analysis*, 2021).

Finally, to determine if the demographic variables had any association that influenced the likelihood of endorsing a specific category of not being vaccinated (Issues with accessibility, Medical contraindication, Confliction of beliefs/vaccine hesitancy), separate logistic regression

models were estimated. Odds ratios were estimated for each demographic variable (age, race, ethnicity, sex, rurality) before and after adjusting for the influence of the other variables to show if any group within each stratum was significantly impacted by the demographic variables.

Results

In the COVID-19 GDPH Surveillance dataset downloaded on 12/31/2021 there were 2,355,032 persons under investigation (PUI). After selecting the confirmed COVID-19 cases there were 1,225,176 cases that met those criteria. Restricting to cases aged greater than or equal to 18 years occurring in 2021, the number of cases for analysis was 695,472. These 695,472 confirmed cases form the base sample for descriptive analyses. Due to missing information, the sample size was further restricted for some analyses as specified in the results.

Table 1 presents the count of vaccinated and unvaccinated cases to show the distribution of cases for each month of 2021. The percentage of cases that were vaccinated steadily increased throughout 2021 beginning at 14.7% and peaking at 56.0% at the end of the year in December. There was slight fluctuation during the first 3 months of the year, with the largest jump in the percentage vaccinated occurring from July to August (25.9% to 35.7%). The percentage of cases that were unvaccinated individuals was 85.3% in January and fluctuated in the 80-90% range until June. From June to December the percent of cases from unvaccinated individuals decreased consistently to 44.0% by December.

Descriptive characteristics of vaccinated and unvaccinated confirmed cases are given in Table 2. Comparing those who were not vaccinated to those who were vaccinated, 68.6% vs 52.3% were aged 18-49 while 9.9% vs 21.6% were aged 65+ years, respectively. Regarding race, the White group was the largest proportion of the total confirmed cases at 58.8%. The Black or African American group was the next largest group consisting of 37.8% of the confirmed cases followed by the Asian group (3.2%), the American Indian or Alaska Native (0.09%), and the Native Hawaiian or Other Pacific Islander group (0.13%). For Ethnicity the Hispanic/Latino group consisted for 10.7% of the confirmed cases while 89.3% of the confirmed cases was in the Not

Hispanic/Latino group Regarding sex, male was a smaller proportion of the confirmed cases (42.9%) than female (57.1%). Regarding Rurality, 98.2% of the confirmed cases lived in a 'Metro' region and 1.8% of the confirmed cases lived in a 'Non-metro' region.

Table 3 indicates the unadjusted and adjusted odds ratio (OR) for being unvaccinated among individuals who are confirmed cases of COVID-19 associated with demographic factors such as age, race, ethnicity, sex, and rurality. There was an unadjusted association between age and an being unvaccinated. Among confirmed COVID-19 cases, being in the 18-49 year old age group and in the 50-64 year old age group was associated with higher relative odds of being unvaccinated compared with being in the 65+ years age group (OR=2.85, 95% CI: 2.76, 2.94 and OR=1.78, 95%CI: 1.72, 1.84, respectively) after adjusting for race, ethnicity, sex, and rurality.

Compared with White adults, the Black and Asian groups had higher relative odds of being unvaccinated confirmed COVID-19 cases (OR=1.37, 95% CI: 1.34, 1.40 and OR=0.54 95% CI: 0.51, 0.57, respectively). After controlling for age, ethnicity, sex, and rurality, the Black group had an OR of 1.25 (CI: 1.22, 1.29) while the Asian group had an OR of 0.46 (95% CI: 0.43, 0.49).

The unadjusted OR between ethnicity and being unvaccinated was OR=0.74 (95%CI: 0.72, 0.77) when comparing 'Hispanic/Latino' with 'Not Hispanic/Latino' adults with confirmed COVID-19. The adjusted OR=0.94 (95% CI: 0.90, 0.99), showed that the Hispanic/Latino group still had a higher likelihood of being unvaccinated and confirmed COVID-19 positive than the Not Hispanic/Latino group after accounting for age, race, sex, and rurality.

The unadjusted OR of being an unvaccinated and confirmed COVID-19 positive case in females was OR=0.95 (95% CI: 0.93, 0.96) compared to males. After adjusting for age, race, ethnicity,

and rurality the OR of being an unvaccinated and confirmed COVID-19 case for females when compared to males was 0.91 (95% CI: 0.89, 0.93)

The unadjusted OR of being a vaccinated and confirmed COVID-19 case among people living in a non-metro area was 1.15 (95% CI: 1.06, 1.25) when compared with people living in a metro. After adjusting for age, race, ethnicity, and rurality, the OR for people being an unvaccinated, confirmed COVID-19 case and living in a non-metro area compared to people living in a metro area was 1.38 (95% CI: 1.27, 1.51).

Table 4 shows the distribution of the given reasons why people who had confirmed COVID-19 reported that they were not vaccinated or chose to be unvaccinated (n=163935 respondents among confirmed cases). Nine specific reasons were queried: no access, inconvenience, too expensive, religious exemption, philosophical objection, parental/patient refusal, forgot to vaccinate, concurrent illness, and medical contraindication. 'No access' was the most frequently cited reason (33.53% of cases). Following access, 'philosophical objection' (8.75%) and 'parental/patient refusal' (8.57%) were the next most frequently cited reasons. The remaining reasons give had significantly lower endorsement, below 4% of cases for each item. the least frequent reason was 'too expensive' (0.03% of cases).

Table 5 displays the correlation matrix among the reasons given for why a COVID-19 vaccine was not taken by people who had confirmed COVID-19 cases. Generally, there was a low degree of correlation among the reasons. The values are all close to zero and there is a mixed distribution of positive correlations and negative correlations. the largest correlation coefficient is between 'no access' and 'parental/patient refusal' (r=-0.2034). The smallest correlation coefficient is between 'medical contraindication' and 'concurrent illness' (r=-0.00001).

Table 6 shows the principal component analysis (PCA) results. This includes the eigenvector and eigenvalue values by each of the 9 responses. The first Principal Component (PC1) had an eigenvalue of 1.28 and explained 14.21% of the variation in reasons for not being vaccinated. For PC1 closely weighted factors were 'philosophical objection' and 'parental/patient refusal'. PC2 had an eigenvalue of 1.09 and explained 12.16% of the variation. For PC2 closely weighted factors were 'inconvenience' and 'forgot to vaccinate'. PC3 had an eigenvalue of 1.06 and explained 11.82% of the variation.

Table 7 shows the unadjusted and adjusted odds ratios (OR) for the likelihood of refusing the COVID-19 vaccine due to issues with three categories of vaccine inability or hesitancy, modeled as separate outcomes: Accessibility (the composite of No Access, Inconvenience, and Too Expensive responses), Beliefs (the composite of Religious Exemption, Philosophical Objection, and Parental/Patient Refusal responses), or Medical Reasons (the composite of Medical Contraindication, Forgot to Vaccinate, and Concurrent Illness responses) among positive COVID-19 cases based on demographic variables such as age, race, ethnicity, sex, and rurality.

The adjusted OR between older age and reporting accessibility barriers to vaccination was 1.24 (95% CI: 1.21, 1.28) for the 50-64 years old age group and 0.94 (95% CI: 0.90, 0.98) for the 65+ years old where the 18-49 year old age group was the reference group. After adjusting for race, ethnicity, sex, and rurality the ORs for the 50-64 year old and the 65+ year old groups to claim issues with accessibility as a reason to not get vaccinated were 1.23 (95%CI: 1.20, 1.27) and 0.93 (95% CI: 0.89, 0.97) when compared to the 18-49 year old age group.

Relative to White adults (reference), the Black group had OR=0.79 (95% CI: 0.77, 0.81) and the Asian group had OR=1.96 (95% CI: 1.82, 2.12) when considering accessibility issues as a reason for not getting vaccinated. After adjusting for age, ethnicity, sex, and rurality the OR for the

Black group was 0.82 (95% CI: 0.80, 0.84) and the adjusted OR for the Asian group was 2.01 (95% CI: 1.86, 2.17).

The unadjusted OR for Non-Hispanic/Latinos stating accessibility issues as a reason to not get the COVID-19 vaccine was 0.75 (95% CI: 0.71, 0.78) when compared to the likelihood of the Hispanic/Latino group (reference) making the same claims about accessibility issues. After adjusting for age, race, sex, and rurality the adjusted odds ratio for the same measure was 0.78 (95% CI: 0.74, 0.82).

Relative to males (reference) the females had OR=0.88 (95% CI: 0.86, 0.90) in unadjusted models for accessibility issues as a reason for not getting vaccinated. After adjusting for age, race, ethnicity, and rurality the OR for females using accessibility issues as a reason to not get the COVID-19 vaccine was 0.90 (95% CI: 0.88, 0.92) compared to the males.

Compared to people living in Metro areas (reference), the unadjusted OR for people living in Non-metro areas to claim accessibility issues as a reason for not getting the COVID-19 vaccine was 0.83 (95% CI: 0.76, 0.90). After adjusting for age, race, ethnicity, and sex the OR of people living in Non-metro areas using accessibility issues as a reason for not getting the COVID-19 vaccine was 0.80 (95% CI: 0.73, 0.87) compared to those living in Metro areas.

The unadjusted OR between age and stating confliction with beliefs as a reason to not receive the COVID-19 vaccine among the 50-64 year old age group was 0.77 (95% CI: 0.74, 0.80) and among the 65+ year old age group was 0.67 (95% CI: 0.64, 0.71) compared to the 18-49 year old age group (reference). After adjusting for race, ethnicity, sex, and rurality the ORs were higher for the age groups 50-64 and 65+ compared to the 18-49 year old age group (reference) (OR=0.74, 95% CI: 0.71, 0.77 and OR=0.63, 95% CI: 0.60, 0.67, respectively).

Relative to the White adults (reference), the unadjusted OR for stating personal beliefs as a reason to not receive the COVID-19 vaccine for the group (OR=0.29, 95% CI: 0.25, 0.34). After adjusting for age, ethnicity, sex, and rurality the ORs for the Black and Asian groups for stating personal beliefs as a reason for not getting the COVID-19 vaccine were (OR=0.90, 95% CI: 0.87, 0.93; and OR=0.26, 95% CI: 0.23, 0.31).

The unadjusted OR comparing the Non-Hispanic/Latino group to the Hispanic/Latino group (reference) for stating beliefs as a reason to not receive the COVID-19 vaccine was 1.63 (95% CI: 1.52, 1.75). The adjusted OR after accounting for age, race, sex, and rurality was 1.80 (95% CI: 1.67, 1.93).

Relative to males (reference), the unadjusted OR of stating beliefs as a reason to not get the COVID-19 vaccine among Females was 1.04 (95% CI:1.01, 1.07). After adjusting for age, race, ethnicity, and rurality the OR comparing Females to Males was 1.03 (95% CI: 1.001, 1.06).

Relative to the 18-49 year old group (reference), the unadjusted ORs stating medical reasons as for why the COVID-19 vaccine was not received was 1.19 (95% CI: 1.12, 1.26) for the 50-64 year old group and, 1.67 (95% CI: 1.56, 1.79) for the 65+ year old group. Adjusting for race, ethnicity, sex, and rurality yields an OR of 1.21 (95% CI: 1.14, 1.28) for the 50-64 year old group and 1.71 (95% CI: 1.60, 1.84) for the 65+ year old age group.

Relative to the White group (reference), the OR of the Black group stating medical reasons for why they did not get the COVID-19 vaccine was 1.09 (95% CI:1.04, 1.15) and was 3.07 (95% CI: 1.83, 5.16) for the American Indian or Alaska Native group. Adjusting for age, ethnicity, sex, and rurality yielded an OR of 1.12 (95% CI: 1.07, 1.18) for the Black group and 3.28 (95% CI: 2.00, 5.52) for the American Indian or Alaska Native group.

Relative to males, the unadjusted OR of stating medical reasons for why the COVID-19 vaccine was not taken among Females was 1.24 (95% CI: 1.18, 1.30) After adjusting for age, race, ethnicity, and rurality the OR for females was 1.23 (95% CI: 1.18, 1.30).

Tables and Figures

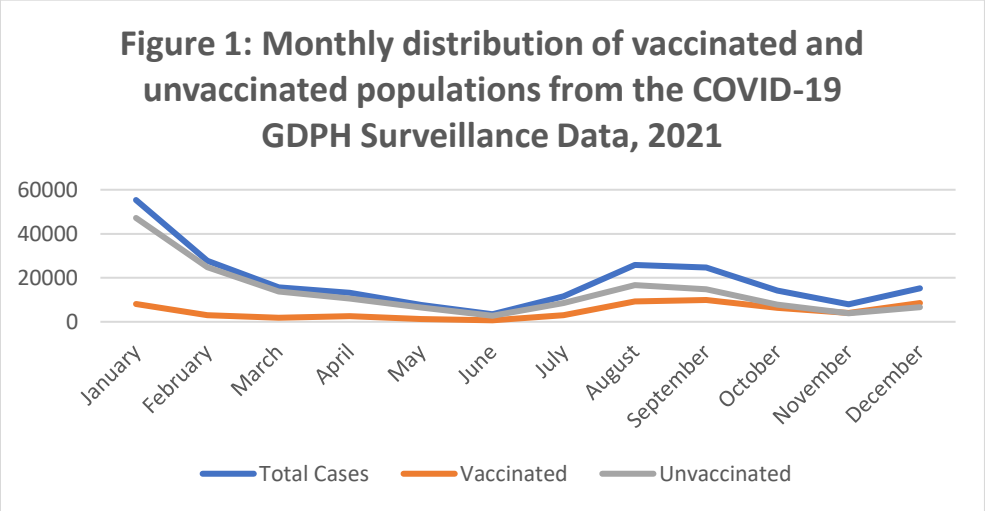

Table 1: Monthly distribution of vaccinated and unvaccinated populations from the COVID-19 GDPH Surveillance Data

		Among Confirmed Cases with Recorded Vaccination Status				Confirmed Cases Missing Vaccination Status
Year	Month	Total Cases	Unvaccinated (n, %)	Vaccinated (n, %)	Percentage of Georgians Vaccinated (%)	Total Cases
2021	January	55331	47201 (85.3)	8130 (14.7)	1.3	91453
	February	27790	24814 (89.3)	2976 (10.7)	6.6	25596
	March	15613	13777 (88.2)	1836 (11.8)	12.8	11189
	April	13151	10637 (80.9)	2514 (19.1)	26.7	9181
	May	7670	6462 (84.3)	1208 (15.7)	33.5	5686
	June	3441	2759 (80.2)	682 (19.8)	36.8	3390
	July	11532	8540 (74.1)	2992 (25.9)	38.8	13138
	August	25865	16624 (64.3)	9241 (35.7)	42.0	83068
	September	24639	14729 (59.8)	9910 (40.2)	45.9	71706
	October	14167	7774 (54.9)	6393 (45.1)	48.5	16851
	November	8001	3903 (48.8)	4098 (51.2)	50.0	7476
	December	15265	6715 (44.0)	8550 (56.0)	51.9	96551
	Jan-Dec Total	222,465	163935	58530	51.9	435285

*Estimated from the GDPH Surveillance Database

**Obtained from CDC COVID Data Tracker for reference (Centers for Disease Control and Prevention, 2022)

Table 2: Demographic Characteristics of Individuals with Confirmed COVID-19 in the State of Georgia: Overall and by Vaccination Status

Variable	Level	Total Confirmed Cases (n, %)	Unvaccinated (n, %)	Vaccinated (n, %)
Age	Group 1: Age 18-49	143157 (64.4)	112534 (68.6)	30623 (52.3)
	Group 2: Age 50-64	50364 (22.6)	35105 (21.4)	15259 (26.1)
	Group 3: Age 65+	28944 (13.0)	16296 (9.9)	12648 (21.6)
Race	White	117254 (58.8)	84152 (57.4)	33102 (62.8)
	Black or African American	75343 (37.8)	58560 (39.9)	16783 (31.8)
	Asian	6358 (3.2)	3669 (2.5)	2689 (5.1)
	American Indian or Alaska Native	178 (0.09)	133 (0.09)	45 (0.09)
	Native Hawaiian or Other Pacific Islander	257 (0.13)	180 (0.12)	77 (0.15)
Ethnicity	Hispanic/Latino	21973 (10.7)	17325 (11.4)	4648 (8.7)
	Not Hispanic/Latino	183940 (89.3)	135157 (88.6)	48783 (91.3)
Sex	Male	95210 (42.9)	70757 (43.2)	24453 (41.9)
	Female	126918 (57.1)	92956 (56.8)	33962 (58.1)
Rurality	Metro	183383 (98.2)	135144 (98.1)	48239 (98.4)
	Non-metro	3375 (1.8)	2576 (1.9)	799 (1.6)

Table notes: % shows the column percentage. Missing data were as follows: age, n = 0; race, n=143976; ethnicity, n=137065; sex=3953; rurality, n=149043

Table 3: Association of Demographic Characteristics with Likelihood of being Unvaccinated of Confirmed COVID-19 Individuals (n=222,465)

Variable	Level	Overall n (%)	Unvaccinated n (%)	Vaccinated n (%)	Unadjusted Odds Ratio of being Unvaccinated	Adjusted Odds Ratio of being Unvaccinated
Age	Age 65+	28944	16296 (56.3)	12648 (43.7)	ref	ref
	Age 50-64	50364	35105 (69.7)	15259 (30.3)	1.79 (1.73, 1.84)	1.78 (1.72, 1.84)
	Age 18-49	143157	112534 (78.6)	30623 (21.4)	2.85 (2.78, 2.93)	2.85 (2.76, 2.94)
Race	White	117254	84152 (71.8)	33102 (28.2)	ref	ref
	Black or African American	75343	58560 (77.7)	16783 (22.2)	1.37 (1.34, 1.40)	1.25 (1.22, 1.29)
	Asian	6358	3669 (57.7)	2689 (42.3)	0.54 (0.51, 0.57)	0.46 (0.43, 0.49)
	American Indian or Alaska Native	178	133 (74.7)	45 (25.3)	1.16 (0.83, 1.63)	1.37 (0.89, 2.11)
	Native Hawaiian or Other Pacific Islander	257	180 (70.0)	77 (30.0)	0.92 (0.70, 1.20)	0.86 (0.62, 1.19)
Ethnicity	Hispanic/Latino	21973	17325 (78.8)	4648 (21.2)	ref	ref
	Not Hispanic/Latino	183940	135157 (73.5)	48783 (26.5)	0.74 (0.72, 0.77)	0.94 (0.90, 0.99)
Sex	Male	95210	70757 (74.3)	24453 (25.7)	ref	ref
	Female	126918	92956 (73.2)	33962 (26.8	0.95 (0.93, 0.96)	0.91 (0.89, 0.93)
Rurality	Metro	183383	135144 (73.7)	48239 (26.3)	ref	ref
	Non-metro	3375	2576 (76.3)	799 (23.7)	1.15 (1.06, 1.25)	1.38 (1.27, 1.51)

Table notes: % shows row percentage. Adjusted models account for age, race, ethnicity, sex, and rurality simultaneously.

Table 4: Prevalence of Reasons Why Vaccine Was Not Received at the Time of COVID-19 Confirmation		
Reason	Count of Cases Stating Specific Reason for Hesitancy	Percentage of Cases
No Access	54960	33.53
Inconvenience	2538	1.55
Too Expensive	54	0.03
Religious Exemption	493	0.30
Philosophical Objection	14345	8.75
Parental/Patient Refusal	14046	8.57
Forgot to Vaccinate	1517	0.93
Concurrent Illness	5580	3.40
Medical Contraindication	2763	1.69

Total sample size included all adult confirmed cases reporting not being vaccinated at the time of infection: n =163935

Table 5: Correlation Matrix of Outcomes for Reasons Why Vaccine was not Received (n=163935)									
Outcomes (Correlation score 0-1)	**No Access**	**Religious Exemption**	**Medical Contraindication**	**Philosophical Objection**	**Parental/Patient Refusal**	**Forgot to Vaccinate**	**Inconvenience**	**Too Expensive**	**Concurrent Illness**
No Access	1	-0.03428	-0.07833	-0.19714	-0.20336	-0.06431	-0.07827	-0.00363	-0.09355
Religious Exemption	-0.03428	1	0.00752	0.00389	-0.01084	-0.00531	-0.00598	-0.001	-0.00908
Medical Contraindication	-0.07833	0.00752	1	-0.01254	-0.02671	-0.01117	-0.00721	0.00023	-0.00001
Philosophical Objection	-0.19714	0.00389	-0.01254	1	-0.05562	-0.02452	-0.02782	-0.00443	-0.04099
Parental/Patient Refusal	-0.20336	-0.01084	-0.02671	-0.05562	1	-0.0248	-0.02974	-0.00556	-0.02165
Forgot to Vaccinate	-0.06431	-0.00531	-0.01117	-0.02452	-0.0248	1	0.07302	0.00176	-0.01357
Inconvenience	-0.07827	-0.00598	-0.00721	-0.02782	-0.02974	0.07302	1	0.01406	-0.01509
Too Expensive	-0.00363	-0.001	0.00023	-0.00443	-0.00556	0.00176	0.01406	1	-0.00341
Concurrent Illness	-0.09355	-0.00908	-0.00001	-0.04099	-0.02165	-0.01357	-0.01509	-0.00341	1

Table 6: Principal Component Analysis (PCA) Results			
Outcome (Eigenvectors)	**Principal 1**	**Principal 2**	**Principal 3**
No Access (1)	-0.759602	-0.009305	0.008997
Inconvenience (2)	0.148641	0.67529	-0.001837
Too Expensive (3)	0.001555	0.137548	0.01763
Religious Exemption (4)	0.076317	-0.056661	0.201397
Philosophical Objection (5)	0.400396	-0.194275	0.685765
Parental/Patient Refusal (6)	0.418361	-0.228063	-0.629082
Medical Contraindication (7)	0.148422	-0.034897	0.145009
Forgot to Vaccinate (8)	0.127179	0.654006	-0.014855
Concurrent Illness (9)	0.146756	-0.055402	-0.267914
Eigenvalue	1.28	1.09	1.06
Proportion of variance explained	14.21%	12.16%	11.82%

Table 7: Logistic Regression Results (n = 118884)							
		Accessibility OR (95% CI)		**Beliefs OR (95% CI)**		**Medical Reason OR (95% CI)**	
		Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Age, years	Age 18-49 years old	Ref	Ref	Ref	Ref	Ref	Ref
	Age 50-64 years old	1.24 (1.21, 1.28)	1.23 (1.20, 1.27)	0.77 (0.74, 0.80)	0.74 (0.71, 0.77)	1.19 (1.12, 1.26)	1.21 (1.14, 1.28)
	Age 65+ years old	0.94 (0.90, 0.98)	0.93 (0.89, 0.97)	0.67 (0.64, 0.71)	0.63 (0.60, 0.67)	1.67 (1.56, 1.79)	1.71 (1.60, 1.84)
Race	White	Ref	Ref	Ref	Ref	Ref	Ref
	Black or African American	0.79 (0.77, 0.81)	0.82 (0.80, 0. 84)	0.98 (0.95, 1.01)	0.90 (0.87, 0.93)	1.09 (1.04, 1.15)	1.12 (1.07, 1.18)
	Asian	1.96 (1.82, 2.12)	2.01 (1.86, 2.17)	0.29 (0.25, 0.34)	0.26 (0.23, 0.31)	0.79 (0.66, 0.95)	0.84 (0.70, 1.00)
	American Indian or Alaska Native	1.02 (0.69, 1.51)	0.97 (0.66, 1.44)	0.62 (0.35, 1.11)	0.65 (0.36, 1.16)	3.07 (1.83, 5.16)	3.28 (2.00, 5.52)
	Native Hawaiian or Other Pacific Islander	1.35 (0.96, 1.90)	1.31 (0.93, 1.86)	0.90 (0.57, 1.42)	0.92, 0.58, 1.46)	0.38 (0.12, 1.18)	0.40 (0.13, 1.26)
Ethnicity	Hispanic/Latino	Ref	Ref	Ref	Ref	Ref	Ref
	Not Hispanic/Latino	0.75 (0.71, 0.78)	0.78 (0.74, 0.82)	1.63 (1.52, 1.75)	1.80 (1.67, 1.93)	1.13 (1.02, 1.25)	1.04 (0.94, 1.15)
Gender	Male	Ref	Ref	Ref	Ref	Ref	Ref
	Female	0.88 (0.86, 0.90)	0.90 (0.88, 0.92)	1.04 (1.01, 1.07)	1.03 (1.00, 1.06)	1.24 (1.18, 1.30)	1.23 (1.18, 1.30)
Rurality	Metro	ref	ref	ref	ref	ref	ref
	Non-metro	0.83 (0.76, 0.90)	0.80 (0.73, 0.87)	1.07 (0.97, 1.19)	1.06 (0.95, 1.18)	0.88 (0.73, 1.05)	0.85 (0.71, 1.02)

Footnote: Outcome definitions: Accessibility reasons include No Access, Inconvenience, and Too Expensive responses; Belief reasons include Religious Exemption, Philosophical Objection, and Parental/Patient Refusal responses; Medical Reasons include Medical Contraindication, Forgot to Vaccinate, and Concurrent Illness responses

Discussion, Limitations, and Interpretation

The Georgia Department of Public Health (GDPH) COVID-19 Surveillance data revealed much information of the COVID-19 pandemic including trends over time, susceptibility to infection or breakthrough cases, reasons against vaccination, among other outcomes. 222,465 of the 695,472 confirmed cases reported data on whether the vaccine was received or not. Of those confirmed cases, 163,935 were not vaccinated. Among the reasons given, 'lack of access' was the most commonly stated reason given for not being vaccinated, with 'philosophical objection' and 'parental/patient refusal' being the next two more common reasons stated. However, lack of access was almost 4 times as likely to be selected as a reason why the vaccine was not received at the time of infection than either philosophical objection and parental or patient refusal. Lack of access and other issues with accessibility, like expenses or inconvenience, significantly affected younger and middle aged Georgians, Asian Georgians, and those living in metro parts of Georgia. Vaccine hesitancy as it pertains to conflictions of beliefs significantly affected younger Georgians, white Georgians, and females. Medical reasons significantly impacted middle aged and older Georgians as well as Black and American Indian Georgians and females.

We found that demographic characteristics influenced the likelihood of being an unvaccinated case. Age, race and ethnicity, sex, and rurality all had significant impacts in whether someone was not vaccinated as well as the reasons why they were not vaccinated.

Age

The younger age demographic (18-49 years) had a significantly higher likelihood of being unvaccinated. As previously mentioned, the increased quality of life for successive generations may have been a factor convincing younger individuals that vaccinations are unnecessary and can detract from the robustness of an otherwise healthy individual. An additional factor to

consider is the availability of the COVID-19 vaccine. Until April 19, 2021 the COVID-19 vaccine was only offered to frontline healthcare workers, individuals at risk for severe illness and individuals over the age of 64 years old within the state of Georgia (*COVID-19 Vaccination Plan: Georgia*, 2021). Since this analysis looks specifically at 2021, the delay in vaccine availability for all adults may be why we see a higher likelihood for being unvaccinated among the younger age groups (Assistant Secretary for Public Affairs (ASPA), 2022).

Focusing on why the unvaccinated were unvaccinated at time of infection, for accessibility the 65+ year old group was the least affected. Given the priority to vaccinate individuals over the age of 64 during the initial release of the COVID-19 vaccine it is likely that people in that age group would not have had a difficult time finding vaccination sites or opportunities to be vaccinated. As mentioned, in 2021 many individuals under the age of 65 were not eligible for the vaccine until April 2021 leading to the higher rate of unvaccinated individuals under 65 years of age stating accessibility as their main deterrent. The higher likelihood of younger (18-49) individuals to use confliction of beliefs as a reason for not getting the vaccine echoes the earlier sentiment that younger age groups may view vaccines as unnecessary. There is the idea that young people have "lower risk perception" and "are usually healthy, and often have mild symptoms after being infected with COVID-19" leading them to engage in riskier behaviors and forgoing preventive measures (Troiano and Nardi, 2021). During clinical trials for the COVID-19 vaccine "several particularly vulnerable groups in the population were not included in sufficient numbers" leaving a lack of understanding how the vaccine would impact "the elderly, children, patients with allergic reactions" among other communicable and non-communicable diseases (Mohseni Afshar *et al.,* 2021). Given the overlap between being elderly and having a comorbidity as well as the uncertainty at the time how the vaccine might affect someone in this

group, the higher likelihood of older individuals to have medical reasons preventing them from being vaccinated may have been due to the precautionary measures taken during initial vaccine rollout.

Race and Ethnicity

Mentioned earlier and affirmed through this analysis, the Black race group had a significantly higher likelihood of being unvaccinated than other races. This may be due the vast history of medical mistreatment and racism within the public health field. The historically poor relationship between the Black race group and the healthcare industry as a result has likely exacerbated vaccine hesitancy. However, race related vaccine hesitancy extends to other minority groups such as Asians, American Indians, or Hispanic/Latinos as well. Barriers outside of personal decision also appear to affect these groups such as lack of accessibility and medical contraindications. In certain cases, cultural disconnect or miscommunications can lower vaccination rates but in other cases neglect may also play a role. While issues with technology in the form of a "lack of a centralized system… to register for and schedule vaccination appointments" or the "complexity of the vaccine scheduling system" discouraging vaccination efforts, proximity also plays a factor (Njoku, Joseph and Felix, 2021). Inability to prioritize vaccination sites in minority communities are evident when "data show that COVID-19 vaccine locations tend to be disproportionately clustered in more affluent zip codes with lower minority populations" (Njoku, Joseph and Felix, 2021). The disregard for minority and low socioeconomic status (SES) communities indicate that what may be viewed as an issue of hesitancy or beliefs regarding vaccination may include a larger issue of negligence to accessibility when providing vaccination opportunities.

Among these minority race groups that were unvaccinated, the most affected by the lack of accessibility was the Asian group. While it has been reported that the percentage of unvaccinated Asian-Americans is low, there is a wider issue when it comes to accessibility to the vaccination. Like issues mentioned above regarding race, there are problems in participation of health research studies with many minority groups, including Asians. What can be attributed to "lack of trust in research as well as significant language barriers" diminish the generalizability of findings on Asians and restricts their representation when it comes to vaccine rollout development (Young and Cho, 2021). The misrepresentation that occurs when categorizing and labeling members of the Asian group are "particularly harmful because it disguises Asian subgroup disparities and leads to inaccurate conclusions about the need for interventions and research (Young and Cho, 2021). Failure to tailor interventions, such as using appropriate language or translations during clinical trials or at vaccination sites, can prevent vaccine access to Asians who may not speak English or have other language barriers.

The White group had the highest likelihood of vaccine hesitancy due to their beliefs compared to all other race groups. Regarding vaccine hesitancy in general, indifference or complacency to a particular intervention has been described as an obstacle to public health, particularly among "generally young and majority white" individuals where the complacency could be "characterized as true apathy" (Quinn *et al.,* 2016). The inability to understand or care about the risks of being unvaccinated appear to play a significant role in lower vaccination rates.

The Black and American Indian groups both were significantly more likely to have medical reasons preventing them from being vaccinated than the White group. Concurrent illnesses and medical contraindications may have played a role similar to the same issues for the older age groups previously mentioned. Given the delay of vaccine rollout towards mid-2021, a personal

decision or decision made by a medical professional may have been to hold off on receiving vaccinations until further studies have been carried out on similar at-risk groups. Coupled with previously mentioned issues such as lower representation of minorities in health research studies and lack of access to vaccines, the medical reasons preventing the Black and American Indian groups may also be due to additional factors that could exacerbate concurrent health issues.

Sex

Our analysis showed that males were more likely than females to be unvaccinated against COVID-19. Factors influencing this outcome include a general increased willingness on behalf of females to seek out healthcare treatments more actively as well as the impact of occupation on vaccination status. Specifically, the higher likelihood of females to be vaccinated could be due to the propensity of "women seeking and using preventive care services, or women working in sectors that were prioritized for early vaccination, such as health care and education (Birhane *et al.*, 2021). Regarding the early access of the vaccine to women due to working in high-exposure fields, we found that males were more likely to have accessibility issues when it came to being vaccinated. Similar to the issues younger Georgians had with accessing the vaccine during the initial rollout, males may have had similar issues compared to females given the proportions of healthcare and education occupations (earlier access to vaccine) by sex more towards females as mentioned by Birhane (Birhane *et al.*, 2021).

Even though they had a lower likelihood of being unvaccinated overall, females were more likely to be unvaccinated due to a confliction of beliefs with the COVID-19 vaccine. The general concern about the vaccine came from issues regarding safety of the vaccine. Main concerns regarding the COVID-19 vaccine by women were "about the safety of vaccines and expressing a lack of trust in the quality and impartiality of information provided by healthcare professionals"

(Troiano and Nardi, 2021). In addition to mistrust in the legitimacy of the COVID-19 vaccine, females were more likely to cite medical reasons. A main factor contributing to these medical reasons include pregnancy and the health effects it has on the body. “Pregnant women have… been recognized as a key population in which to study vaccine hesitancy” where concerns about vaccine safety towards children are called into question” (Rosso *et al.*, 2020). The health risks to the mother and their child appear significant enough to prevent full trust in the vaccine for some women. However, it should be noted that “attitudes relating to the importance of vaccines… may be depend on the infectious disease in question” (Rosso *et al.*, 2020). This instance of medical reasoning also aligns closely with the idea of vaccine hesitancy due to belief, where the vaccine-adverse group may be persuaded to the contrary.

Rurality

Compared to people living in metro areas, people living in non-metro areas were more likely to be unvaccinated. However, people living in urban/metro parts of the state of Georgia were more likely to state having issues with accessibility for why they were not vaccinated at time of infection. The difference in accessibility comparing a city setting to a rural setting certainly plays a role. During the initial release of the vaccine, mass vaccination sites were established to facilitate vaccinations of as many people as possible. These sites allowed people living in rural, less populous areas who wanted to receive the vaccine have easier access to getting vaccinated then they typically would. In contrast, the mass vaccination sites of urban areas may not have had the resources to vaccinate all the people who wanted to be vaccinated given the larger metro populations and subsequent higher demands.

The clustering explored using PCA in Table 6 showed multiple correlations including one between the ‘inconvenience’ and ‘forgot to vaccinate’ reasons and another between ‘philosophical objection’ and ‘parental or patient refusal’ also indicated a cluster of interest. ‘Inconvenience’ and ‘forgot to vaccinate’ reasons indicate that the decision to forgo vaccination may be one of apathy. Even for the influenza vaccine “complacent non-takers perceived a low susceptibility and low severity of seasonal influenza as justifications to forego vaccination” (Quinn *et al.,* 2016). Given the wide range of reported symptoms and experiences with COVID-19, individuals may not see the disease as a big enough threat to their day-to-day life. The correlations between ‘philosophical objection’ and ‘parental or patient refusal’ aligns with the idea that a general confliction in beliefs plays an influential role in whether people get vaccinated. Given the expedited process in which the COVID-19 vaccine was developed, there were many people who were concerned with the safety of receiving the vaccine. In fact, “people who believed the COVID-19 vaccine was unsafe were less willing to receive the vaccine, knew less about the virus and were more likely to believe COVID-19 vaccine myths” indicating that a lack of vaccine information was a contributing factor to low vaccination rates (Kricorian, Civen and Equils, 2021). Understanding the personal philosophies of these groups poses a difficult challenge given the many factors that play a role in defining a person’s philosophy: education, political beliefs, and SES.

Secondary Analysis

In 2021, proportion of vaccination among confirmed COVID-19 cases increased while the proportion of no vaccination decreased. In fact, vaccinated cases had a higher total count and prevalence for November and December. However, given the increased number of people who

were vaccinated as the year progressed, the pool of vaccinated people who could get COVID-19 has increased while the potential number of unvaccinated cases has decreased. Additionally, the introduction of at-home testing has decreased the overall number of cases being reported to the GDPH. In addition to the larger pool of people who are vaccinated, the increase in vaccinated cases is also likely due to the increase in prominence of the delta and omicron variants of COVID-19 which the initial COVID-19 vaccine had varying levels of success against (Rosenberg *et al.*, 2022). By middle of the summer 2021 the omicron variant became a key contributor to the many COVID-19 cases and the vaccine had a much lower success rate against it (Hoffmann *et al.*, 2022).

Strengths and Limitations

The GDPH COVID-19 surveillance data offered a broad overview of how the state of Georgia has been dealing with the COVID-19 pandemic. Fairly consistent and comprehensive data on the age, race, ethnicity, sex, and rurality of confirmed cases offered useful interpretations of the data that could be applied to the state of Georgia. The additional information on whether an individual received the COVID-19 vaccine and if not then why allows for a better understanding of why low vaccination rates were able to persist towards the end of 2021.

However, response within the GDPH surveillance data set was sporadic, specifically for the 'vaccine received' portion. Data reporting on whether the COVID-19 vaccine was taken had the largest number of missing values with 473007 of the 695,472 (68.0%) confirmed cases missing. Table 1 shows the missing data by time indicating that data had more missing values at the start and end of 2021. The analysis was carried out on the data that was available. Since this was data from the COVID-19 surveillance system for the whole state of Georgia, we were able to analyze data from all cases reported to GDPH. However, it is unlikely that all individuals with COVID-

19 were captured in this database because of under testing, and at-home testing kits, which led to the reduction of institutional testing with mandatory reporting. As a result, the confirmed COVID-19 cases that were used for this analysis represent the number of Georgia residents who were able to be tested at facilities that share data and information with the GDPH rather than the whole state of Georgia. During analysis, the 'forgot to vaccinate' response was categorized as a 'medical reason'. However, in the future it may be more appropriate to categorize those who used this response as 'vaccine hesitant'/'beliefs' because they could be persuaded to vaccinate as opposed to the 'medical reasons' group who are unlikely to be vaccinated.

Key Findings and Implications

Low vaccination rates have shown to be associated with younger Georgians, Black Georgians, Hispanic/Latinos, males, as well as those who live in rural Georgia. The largest obstacle to receiving the vaccine was issues with accessibility representing 54,960 of the 163935 (33.53%) unvaccinated confirmed cases. This analysis was able to identify demographics that have shown greater reservations when it comes to vaccination as well as the reasons why they are not able to be vaccinated. These findings indicate that a lack of accessibility was the more prevalent inhibitor to receiving the COVID-19 vaccine than vaccine hesitancy/confliction of beliefs over the 2021 calendar year. However, it is likely that the prevalences of the reasons why vaccines were not received have changed throughout the pandemic. For example, as 2021 progressed and the vaccine was offered to a wider audience, reported issues of inaccessibility would have gone down.

Ensuring that the vaccine is accessible should be a key component in any vaccine deployment intervention. This includes appropriate locations that are accessible to people lacking reliable

means of transportation or who may live further from current vaccination sites. Furthermore, inaccessibility should be addressed in the form of technology and health literacy. Using a simple online platform that is sensitive to those who are unfamiliar with technology can be encouraging to those who have struggled navigating more confusing vaccination sign-up websites. Those who do not have internet access must also be considered by targeting places of business or locations where they might congregate. Simple language and translating services should be made available when appropriate when recruiting people to get vaccinated and administering the vaccine to benefit those facing language barriers.

We determined that confliction of beliefs do play a role in lower vaccination rates however further analysis is required to understand the specifics of such a multifaceted issue. Concerns with safety behind vaccine development as well as trust with the government were found to play large roles in vaccine hesitancy. To understand how additional social influences determine vaccine outcomes, future analysis on the impact of religion and politics and the roles they play in vaccine rollout can help to ensure proper actions are developed to improve vaccination rates. As for the best way to decrease obstacles additional medical risks bring, ongoing vaccine research is important to understand how immunocompromised or those with contraindications may be impacted by the vaccine.

There is also the wider issue of addressing healthcare within the United States. Lack of access to healthcare professionals or lack of health literacy prevent individuals from making the best decisions for their health. Ensuring that healthcare professionals are available to advise people with complex medical issues allows them to know their most appropriate treatment option. As the COVID-19 pandemic continues it evolves offering new challenges. By looking into the observations from this analysis, public health officials can understand the shortcomings of how

Georgia has dealt with COVID-19 so far. By understanding the best ways to build initiatives that will target low vaccination rate groups and improve vaccination outcomes we hope to bring the COVID-19 pandemic under control.

Bibliography

Alcendor, D.J. (2020) 'Racial Disparities-Associated COVID-19 Mortality among Minority Populations in the US', *Journal of Clinical Medicine*, 9(8), p. 2442. doi:10.3390/jcm9082442.

Assistant Secretary for Public Affairs (ASPA) (2022) *COVID-19 Vaccines*. U.S. Department of Health & Human Services. Available at: https://www.hhs.gov/coronavirus/covid-19-vaccines/index.html.

Aw, J. *et al.* (2021) 'COVID-19 Vaccine Hesitancy—A Scoping Review of Literature in High-Income Countries', *Vaccines*, 9(8), p. 900. doi:10.3390/vaccines9080900.

Birhane, M. *et al.* (2021) *COVID-19 vaccine breakthrough infections reported to CDC — United States, January 1–April 30, 2021*. CDC COVID-19 Vaccine Breakthrough Case Investigations Team: Centers for Disease Control and Prevention. Available at: https://stacks.cdc.gov/view/cdc/106524.

Centers for Disease Control and Prevention (2022) *COVID Data Tracker*. US Department of Health and Human Services, CDC. Available at: https://covid.cdc.gov/covid-data-tracker/#vaccination-trends_vacctrends-total-cum.

Collins, R.N., Mandel, D.R. and Schywiola, S.S. (2021) 'Political Identity Over Personal Impact: Early U.S. Reactions to the COVID-19 Pandemic', *Frontiers in Psychology*, 12, p. 607639. doi:10.3389/fpsyg.2021.607639.

Cornelia Betsch, Constanze Rossmann, and Katrine Bach Habersaat (2017) 'Vaccination and Trust'. Available at: https://www.euro.who.int/__data/assets/pdf_file/0004/329647/Vaccines-and-trust.PDF.

COVID-19 Vaccination Plan: Georgia (2021). Georgia Department of Public Health. Available at: https://dph.georgia.gov/covid-vaccine.

Dubé, E., Vivion, M. and MacDonald, N.E. (2015) 'Vaccine hesitancy, vaccine refusal and the anti-vaccine movement: influence, impact and implications', *Expert Review of Vaccines*, 14(1), pp. 99–117. doi:10.1586/14760584.2015.964212.

Econometrics Academy - Principal Component Analysis (2021). Available at: https://sites.google.com/site/econometricsacademy/econometrics-models/principal-component-analysis (Accessed: 11 November 2021).

Flaherty, D.K. (2011) 'The Vaccine-Autism Connection: A Public Health Crisis Caused by Unethical Medical Practices and Fraudulent Science', *Annals of Pharmacotherapy*, 45(10), pp. 1302–1304. doi:10.1345/aph.1Q318.

Georgia Department of Public Health (2021) *Daily Status Report Data Definitions and FAQs for COVID-19*. Available at: https://dph.georgia.gov/covid-19-daily-status-report.

Hannah Ritchie *et al.* (2020) ‘Coronavirus Pandemic (COVID-19)’. Available at: https://ourworldindata.org/covid-vaccinations.

Hoffmann, M. *et al.* (2022) ‘The Omicron variant is highly resistant against antibody-mediated neutralization: Implications for control of the COVID-19 pandemic’, *Cell*, 185(3), pp. 447-456.e11. doi:10.1016/j.cell.2021.12.032.

Hudson, A. and Montelpare, W.J. (2021) ‘Predictors of Vaccine Hesitancy: Implications for COVID-19 Public Health Messaging’, *International Journal of Environmental Research and Public Health*, 18(15), p. 8054. doi:10.3390/ijerph18158054.

Khan, M.S. *et al.* (2021) ‘Rethinking vaccine hesitancy among minority groups’, *The Lancet*, 397(10288), pp. 1863–1865. doi:10.1016/S0140-6736(21)00938-7.

Khan, M.S.R., Watanapongvanich, S. and Kadoya, Y. (2021) ‘COVID-19 Vaccine Hesitancy among the Younger Generation in Japan’, *International Journal of Environmental Research and Public Health*, 18(21), p. 11702. doi:10.3390/ijerph182111702.

King, W.C. *et al.* (2021) ‘COVID-19 vaccine hesitancy January-May 2021 among 18–64 year old US adults by employment and occupation’, *Preventive Medicine Reports*, 24, p. 101569. doi:10.1016/j.pmedr.2021.101569.

Kricorian, K., Civen, R. and Equils, O. (2021) ‘COVID-19 vaccine hesitancy: misinformation and perceptions of vaccine safety’, *Human Vaccines & Immunotherapeutics*, pp. 1–8. doi:10.1080/21645515.2021.1950504.

Kumar, D. *et al.* (2016) ‘Vaccine hesitancy: understanding better to address better’, *Israel Journal of Health Policy Research*, 5(1), p. 2. doi:10.1186/s13584-016-0062-y.

MacDonald, N.E. (2015) ‘Vaccine hesitancy: Definition, scope and determinants’, *Vaccine*, 33(34), pp. 4161–4164. doi:10.1016/j.vaccine.2015.04.036.

McAteer, J., Yildirim, I. and Chahroudi, A. (2020) ‘The VACCINES Act: Deciphering Vaccine Hesitancy in the Time of COVID-19’, *Clinical Infectious Diseases*, 71(15), pp. 703–705. doi:10.1093/cid/ciaa433.

Mohseni Afshar, Z. *et al.* (2021) ‘Coronavirus disease 2019 (Covid-19) vaccination recommendations in special populations and patients with existing comorbidities’, *Reviews in Medical Virology* [Preprint]. doi:10.1002/rmv.2309.

Murthy BP, Sterrett N, Weller D, et al. (2021) ‘Disparities in COVID-19 Vaccination Coverage Between Urban and Rural Counties — United States, December 14, 2020–April 10, 2021’. Available at: https://www.cdc.gov/mmwr/volumes/70/wr/mm7020e3.htm?s_cid=mm7020e3_w#suggestedcitation.

Njoku, A., Joseph, M. and Felix, R. (2021) 'Changing the Narrative: Structural Barriers and Racial and Ethnic Inequities in COVID-19 Vaccination', *International Journal of Environmental Research and Public Health*, 18(18), p. 9904. doi:10.3390/ijerph18189904.

O'Connor, A. and Wellenius, G. (2012) 'Rural–urban disparities in the prevalence of diabetes and coronary heart disease', *Public Health*, 126(10), pp. 813–820. doi:10.1016/j.puhe.2012.05.029.

Quinn, S. *et al.* (2016) 'Exploring the Continuum of Vaccine Hesitancy Between African American and White Adults: Results of a Qualitative Study', *PLoS Currents* [Preprint]. doi:10.1371/currents.outbreaks.3e4a5ea39d8620494e2a2c874a3c4201.

Rosenberg, E.S. *et al.* (2022) 'Covid-19 Vaccine Effectiveness in New York State', *New England Journal of Medicine*, 386(2), pp. 116–127. doi:10.1056/NEJMoa2116063.

Rosso, A. *et al.* (2020) 'Factors affecting the vaccination choices of pregnant women for their children: a systematic review of the literature', *Human Vaccines & Immunotherapeutics*, 16(8), pp. 1969–1980. doi:10.1080/21645515.2019.1698901.

SAS/ACCESS® 9.4 Interface to ADABAS (2013). SAS Institute Inc.

Sun, Y. and Monnat, S.M. (2021) 'Rural-urban and within-rural differences in COVID-19 vaccination rates', *The Journal of Rural Health*, p. jrh.12625. doi:10.1111/jrh.12625.

Tram, K.H. *et al.* (2021) 'Deliberation, Dissent, and Distrust: Understanding Distinct Drivers of Coronavirus Disease 2019 Vaccine Hesitancy in the United States', *Clinical Infectious Diseases*, p. ciab633. doi:10.1093/cid/ciab633.

Troiano, G. and Nardi, A. (2021) 'Vaccine hesitancy in the era of COVID-19'.

Tuskegee Study - Frequently Asked Questions - CDC - NCHHSTP (2021). Available at: https://www.cdc.gov/tuskegee/faq.htm (Accessed: 11 November 2021).

Willis, D.E. *et al.* (2021) 'COVID-19 vaccine hesitancy: Race/ethnicity, trust, and fear', *Clinical and Translational Science*, p. cts.13077. doi:10.1111/cts.13077.

World Health Organization (2022) *WHO Coronavirus (COVID-19) Dashboard*. Available at: https://covid19.who.int/ (Accessed: 14 February 2022).

Young, J.L. and Cho, M.K. (2021) 'The Invisibility of Asian Americans in COVID-19 Data, Reporting, and Relief', *The American Journal of Bioethics*, 21(3), pp. 100–102. doi:10.1080/15265161.2020.1870767.