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Impact of State Vaccine Mandates on Vaccination Coverage Rates During the COVID-19 Pandemic, September 2021 to September 2022

By:

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Degree to be awarded: MPH

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B.S., University of South Carolina, 2014

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An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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2024

Abstract

Impact of State Vaccine Mandates on Vaccination Coverage Rates During the COVID-19 Pandemic, September 2021 to September 2022

By Eliza S. Ballou

Background

The Coronavirus disease 2019 (COVID-19) pandemic, caused by the SARS-CoV-2 virus, led to widespread illness and prompted an urgent need for public health measures to control its spread. Vaccination emerged as a key strategy for mitigating severe outcomes, including hospitalizations and deaths. In response, states in the United States adopted varied policies to address vaccination uptake. Some states implemented mandates requiring vaccination for specific populations, aiming to increase coverage rates and protect public health. Other states enacted prohibitions against mandates, reflecting diverse political and social contexts that prioritized personal autonomy. A third group of states had no mandates or only one mandate requirement. This study investigates the impact of these state-level COVID-19 vaccination policies on adult vaccination coverage rates from September 2021 to September 2022. The analysis focuses on adults aged 18 and older, excluding mandates related to children, schools, or educational settings, to understand how different policy approaches influenced public health outcomes during the pandemic.

Methods

Vaccination data from the Immunization Information System (IIS), national census estimates for state populations in 2021 and 2022, State and Legislative Control data for 2020 from the National Conference of State Legislature (NCSL), and state vaccine mandate data from the Centers for Disease Control and Prevention (CDC) were used to assess the impact of state vaccine mandates on state-level vaccination coverage rates. The mandate type of each state was used as the exposure and state-level vaccination counts from September 1, 2021, and September 7, 2022, were used as the outcome. Poisson regression was used to estimate the vaccination rate ratios (VRR) and 95% Confidence Intervals (CI) between each type of mandate at the two time periods, assessing the impact of vaccine mandates while controlling for state political power in 2020.

Results

The 50 states and Washington D.C. were analyzed at two time periods, 2021 and 2022. Controlling for state political power in 2020, states with required mandates had higher vaccination coverage rates than states with no mandates (VRR: 2021, 1.10 95% CI 1.01-1.20 and 2022, 1.11 95% CI 1.02-1.22). States with mandate prohibitions had lower vaccination rates than states with no mandates (VRR: 2021, 0.91 95% CI 0.85-0.97 and 2022, 0.92 95% CI 0.86-0.98), and states with mandate requirements (VRR: 2021, 0.82 95% CI 0.75-0.90 and 2022, 0.83 95% CI 0.75-0.91).

Conclusions

This study suggests that during the first and second years of COVID-19 vaccine availability, states with vaccine mandate requirements had a higher rate of vaccination coverage than compared to states with no mandates or states with mandate prohibitions. States with mandate prohibitions had lower vaccination coverage rates than all other states. Further research is needed to assess the impact of the federal vaccine mandate and identify unknown and unmeasured confounders during the same period due to data limitations.

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Chapter I: Introduction

The COVID-19 pandemic prompted significant public health interventions, including developing and distributing vaccines to prevent severe disease from severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[1] Once vaccines became available throughout the United States (U.S.), states began implementing COVID-19 vaccination policies.[2,3] The first groups of mandates to be enacted were those prohibiting vaccine mandates requiring people to get vaccinated for COVID-19, starting in Florida on April 2, 2021.[4] In August of 2021, States began to enact mandates requiring COVID-19 vaccination for government and healthcare workers, patrons of businesses, and other groups of people.[5] For all other states that did not create state-level mandates, on September 9, 2021, President Biden enacted a federal vaccine mandate requiring all government employees and healthcare workers funded by the Centers for Medicaid and Medicare Services (CMS) to be fully vaccinated or risk termination from their employment.

The divergence in policy created an opportunity to study the implications of these mandates on vaccination coverage rates, providing valuable insight into the role of state-level mandates in public health outcomes. Understanding the relationship between state vaccine mandates and vaccination coverage rates is crucial for developing informed public health strategies. For this thesis, the study period (September 1, 2021, to September 7, 2022) was selected to encompass key events, including the September 2021 federal mandate, booster dose recommendations, and legal disputes regarding mandates. Given the ongoing challenges in vaccination campaigns, such as vaccine

hesitancy and policy resistance, this research contributes to developing evidence-based policies that optimize public health interventions.

Problem Statement

The COVID-19 pandemic required the rapid rollout of vaccination programs to improve population immunity and prevent severe disease and deaths. However, the varying state policies, either requiring or prohibiting vaccine mandates, may have led to inconsistent vaccination coverage rates across the U.S. While state mandates can serve as tools to improve vaccine uptake, the lack of comprehensive data on the impact of these mandates limits the ability of public health officials to recommend policies that maximize vaccination coverage rates.

This thesis addresses the knowledge gap regarding the effect of state-level mandates on vaccination coverage rates by comparing the outcomes of states with vaccine mandate requirements, those with vaccine mandate prohibitions, and states with no state-level vaccine mandates. Without this information, policymakers are hindered in their ability to design targeted vaccination campaigns and may miss opportunities to implement effective strategies for managing public health crises. This thesis' findings will contribute knowledge that can inform policy decisions in the future.

Theoretical Framework

The Social-Ecological Model provides the framework for this research, emphasizing the interaction of individual, community, and policy-level factors in shaping health

behaviors. Vaccine uptake is not solely a result of individual decision-making but is influenced by broader systemic factors, including state policies. This model allows the study to explore how legislative and executive actions interact with social dynamics and personal health decisions to affect vaccination coverage rates.

Purpose Statement

This study investigates the impact of COVID-19 state vaccine mandate requirements, state vaccine mandate prohibitions, and states with minimal or no state-level vaccine mandates on vaccination coverage rates in the United States from September 2021 to September 2022. It compares vaccination coverage trends among states with vaccine mandate requirements, states with vaccine mandate prohibitions, and states without vaccine mandates, contributing to a better understanding of how policy decisions influence public health outcomes.

Research Question

This study seeks to answer the following research question:

- What is the impact of the following state vaccine mandate types: states with minimal or no state-level vaccine mandates, states with vaccine mandate requirements, and states with vaccine mandate prohibitions on COVID-19 vaccination coverage rates between September 2021 and September 2022?

-Hypothesis: Vaccination coverage rates will be statistically significant differences between states with vaccine mandate prohibitions and states with minimal or no vaccine mandates, states with vaccine mandate requirements and states with minimal or no

vaccine mandates, and states with vaccine mandate prohibitions and states with vaccine mandate prohibitions.

Significance of the Study

The findings from this study can inform public health policy by evaluating the association between state-level vaccine mandate requirements, vaccine mandate prohibitions, and no state-level vaccine mandates on vaccination coverage rates. Policymakers and public health officials can use the results to design targeted interventions that balance individual freedoms with public health goals. Additionally, this research will contribute to the literature on the role of legislative and executive actions in shaping health outcomes, providing a framework for future studies on vaccination policies.

This knowledge is essential not only for preparing for future public health emergencies. Understanding the dynamics between state policies and vaccination coverage rates will enable public health authorities to implement effective and contextually appropriate strategies, minimizing the social and economic costs associated with future outbreaks.

Definition of Terms

- State-level Vaccine Mandates: Policies implemented at the state level requiring vaccination, or prohibiting the requirement of vaccination for specific populations or activities.
- State Vaccine Mandate Requirements: State-imposed requirements for individuals or specific groups to receive a COVID-19 vaccine.

- State Vaccine Mandate Prohibition: State-level orders prohibiting requirements for COVID-19 vaccination.
- Vaccine Uptake: The proportion of the population receiving the recommended vaccine doses at a given time.
- Primary Series: The initial COVID-19 vaccine series required to establish immunity (one or two doses).
- Booster Dose: An additional vaccine dose administered after completing the primary series to enhance or restore immunity.
- Social-Ecological Model: A framework that explores the interaction between individual, community, and policy factors in shaping health behaviors.

This chapter provides the foundation for further investigation into the role of state-level policies in shaping vaccination coverage rates. The following chapters will describe the methodology, data analysis, and results, summarizing the impact of state vaccine mandates and mandate prohibitions on public health.

Chapter II: Review of the Literature

The COVID-19 pandemic has highlighted the importance of effective vaccination strategies as essential tools in public health. With vaccines being a critical means to reduce severe illness, hospitalizations, and death, U.S. state-level policies have played a significant role in shaping public health outcomes. However, the response to COVID-19 vaccination has not been uniform across states, with varying policies implemented to address vaccine uptake. While some states enforced mandates requiring COVID-19 vaccination for specific populations or settings, such as hospitals or medical facilities, others enacted prohibitions on mandates due to political and social considerations. This diverse policy landscape creates a unique context for examining the associations between state policies and COVID-19 vaccination coverage rates. This chapter reviews the literature on vaccination mandates, mandate prohibitions, and the associated public health outcomes.

The COVID-19 Pandemic

COVID-19, caused by the SARS-CoV-2 virus, first emerged in Wuhan, China, in December 2019.[6,7] This highly transmissible, novel virus quickly spread beyond China's borders, reaching numerous countries and having a widespread impact worldwide. By March 11, 2020, the World Health Organization officially declared COVID-19 a pandemic. Cases surging worldwide overwhelmed healthcare systems and resulted in widespread illness, hospitalizations, and death.[8]

The urgent need for effective preventive measures against COVID-19 led to an unprecedented global effort to develop and approve vaccines in record time.[9,10] By the

end of 2020, vaccines from several manufacturers, including Pfizer-BioNTech, Moderna, and Janssen, had received Emergency Use Authorization (EUA) from the U.S. Food and Drug Administration (FDA) to mitigate the impact of COVID-19.[11] Initial studies suggested that vaccines were highly effective in preventing severe illness, hospitalization, and death.[12,13] Clinical trials demonstrated efficacy rates ranging from approximately 89.1% to 99.0% in reducing the risk of severe outcomes, such as hospitalization, intensive care unit (ICU) admission, and death.[14,15] As vaccines were rapidly rolled out in the U.S., from late December 2020 to early 2021, public health officials promoted vaccination as the safest strategy for avoiding the severe health consequences of COVID-19.[16]

Despite the availability of effective vaccines and evidence suggesting that vaccination could significantly reduce transmission and protect vulnerable populations, the U.S. faced challenges in achieving high vaccination uptake across diverse populations.[17] Studies indicate that hesitancy was prevalent among various demographic groups, with specific concerns about personal autonomy tied to political ideology, distrust in the healthcare system, and fears about potential side effects.[18,19] Therefore, states responded with varying policy measures to increase vaccine coverage, ranging from mandate requirements to prohibitions on mandates, reflecting each state's unique political and social climate.

Vaccine Mandate Requirements

In California, Colorado, Connecticut, the District of Columbia, Hawaii, Illinois, Massachusetts, Maine, New Jersey, New Mexico, New York, Nevada, Oregon, Rhode

Island, and Washington, there were vaccine mandate requirements for specific populations, such as healthcare workers and government employees.[20,21] These mandates were designed to ensure high vaccination coverage rates in high-contact environments, thereby protecting vulnerable populations and reducing transmission rates.

Vaccine mandate prohibitions

Beginning in March 2021, 23 states adopted policies explicitly prohibiting vaccine mandates, citing concerns over personal freedoms and governmental overreach. These states—Alabama, Arkansas, Arizona, Florida, Georgia, Iowa, Idaho, Indiana, Kansas, Michigan, Missouri, Mississippi, Montana, North Dakota, New Hampshire, Oklahoma, South Carolina, South Dakota, Tennessee, Texas, Utah, West Virginia, and Wyoming—implemented mandate prohibitions, which prevented businesses, schools, and public agencies from requiring vaccination for employees or patrons[22]. Notably, 16 of these states had vaccine mandate prohibitions in place before the federal government announced the requirement for all federal employees to be vaccinated on September 9, 2021. Several mandate prohibitions originated from executive orders by governors rather than state legislatures. For instance, executive orders enacted mandate prohibitions in Florida, Idaho, Montana, Georgia, Oklahoma, Arizona, Texas, and South Carolina. In Georgia, South Carolina, Arizona, Florida, and Texas, prohibitions were reinforced by both executive orders and legislative action. All other prohibition states relied solely on state legislatures to enact these policies. Various factors, including vaccine hesitancy, mistrust in government institutions, and concerns about personal autonomy, fueled these mandates[23,24]. Vaccine hesitancy, already a recognized issue

before the pandemic, was exacerbated during COVID-19 due to misinformation, concerns about the rapid development and approval of the vaccines, and the absence of data on long-term effects[25]. Studies indicate that hesitancy was prevalent among various demographic groups, with specific concerns tied to political ideology, distrust in the healthcare system, and fears about potential side effects [26].

Minimal or No State-Level Vaccine Mandate

There were also 13 states - Alaska, Delaware, Kentucky, Louisiana, Maryland, Minnesota, North Carolina, Nebraska, Nevada, Ohio, Pennsylvania, Vermont, and Wisconsin - that did not implement comprehensive vaccine mandate requirements or vaccine mandate prohibitions.[21] In these states, there were either no vaccine requirements or mandates were limited to a few specific settings or populations, resulting in a more neutral policy stance.

These diverse responses offer a unique opportunity to assess the impact of state-level policies on vaccination coverage rates. Research suggests that political affiliations and beliefs influenced attitudes toward COVID-19 policies, with conservative-leaning individuals more likely to resist vaccination and oppose mandates.[27] [23] This polarization in public attitudes towards vaccination policy provides the backdrop for this thesis, which will analyze vaccination trends across states with mandate requirements, prohibitions, and minimal or no mandates, providing insight into how policy decisions impact public health outcomes in a politically divided society.

The Impact of Vaccine Mandates in the United States

The United States has a long history of vaccine mandates. For instance, in 1777, General George Washington mandated that all soldiers be inoculated for smallpox.[28] Following the development of the smallpox vaccine in 1798, Massachusetts required smallpox vaccination for the general population in 1809.[29] In the twentieth century, vaccine mandates were primarily used for the military and schools.[30] [31] These vaccine mandates have historically increased vaccine uptake, particularly within these controlled populations.[32] [33]

Several previous evaluations have focused on the effectiveness of vaccine mandates. For instance, in the U.S. military, vaccine mandates have been found to be effective, and vaccination compliance rates have historically been high.[30] According to a previous evaluation of the impact of COVID-19 vaccine mandates within healthcare settings across the U.S., which focused on the success of healthcare worker vaccination mandates, where maintaining high immunization rates was essential to protecting both healthcare workers and vulnerable patient populations, vaccine mandates were found to increase vaccination coverage rates among healthcare personnel significantly.[34] Mandates helped achieve higher vaccination coverage among healthcare workers and contributed to a safer healthcare environment by reducing the potential for viral transmission within these facilities.[34] These studies' findings underscore the importance of mandates in healthcare settings, where the objective of protecting vulnerable populations aligns with the broader public health goal of minimizing virus spread in high-contact, high-risk environments.

In a study to assess the impact of COVID-19 vaccine mandates, vaccination trends across 12 U.S. states and Washington D.C. were analyzed, focusing on areas with initially low vaccine uptake.[35] This study found that vaccination mandates led to significant improvements in compliance, especially in regions where vaccination coverage rates were initially below national averages. It was noted that mandates effectively overcame some of the barriers to vaccination, such as hesitancy and apathy, by creating a structured requirement that individuals must meet for continued employment or access to certain services. In states where mandates were enforced, vaccination coverage rates increased more quickly and reached higher overall levels than in states without mandates or with weaker enforcement mechanisms.[35] This pattern was especially evident in sectors with frequent public interaction, such as healthcare and education, where mandates helped ensure high vaccination coverage. This underscores the potential of mandates requiring vaccination to serve as effective policy tools in achieving higher vaccination coverage rates, particularly in public health emergencies where rapid and widespread immunization is critical.[35]

Mandates have demonstrated value in increasing coverage rates and protecting public health. However, concerns have also been raised about the unintended consequences of COVID-19 vaccine policies, including mandates and vaccine passports. Critics argue that requiring vaccination may exacerbate social inequalities and erode public trust in public health institutions.[36] For many individuals, especially those already skeptical of government overreach, these policies reinforce distrust rather than encourage cooperation. This erosion of confidence can have lasting consequences beyond COVID-

19, potentially affecting public attitudes toward future vaccination campaigns and other public health initiatives.[37]

Impact of Vaccine Mandate Requirements on Healthcare Workers and Vulnerable Populations

The healthcare sector, particularly nursing homes, faced unique challenges regarding COVID-19 vaccination. When examining how vaccine mandates affected vaccination coverage rates among nursing home staff, mandates significantly improved vaccination coverage in these settings.[38] Following the implementation of mandates requiring vaccination with no testing out options, vaccination coverage rates for nursing home staff rose approximately 6% in mandated regions. In contrast, in a nursing home in Mississippi, where the vaccine mandate allowed staff to have a test-out option, there was only a small increase in vaccination coverage rates that was not statistically significant, showing that testing-out policies can be ineffective.[39]

The importance of mandates extends beyond nursing homes to the broader healthcare sector, where high vaccination coverage rates are essential to protect vulnerable populations, particularly immunocompromised individuals.[40] Immunocompromised patients, such as those undergoing chemotherapy, organ transplant recipients, and individuals with autoimmune disorders, face an increased risk of severe outcomes from COVID-19.[41] For these patients, exposure to COVID-19 can result in complications or death, making it essential that healthcare providers who regularly interact with high-risk individuals are vaccinated. Vaccine mandates in hospitals and other healthcare settings are therefore critical in creating safer environments, helping to reduce the

potential for outbreaks within these facilities, and protecting patients with weakened immune systems.[42]

Throughout most of the U.S., COVID-19 vaccine mandates did not result in substantial staffing losses within healthcare settings, including nursing homes and hospitals.[38,46,47] Although vaccine hesitancy remains a concern among some healthcare personnel, studies indicate that mandates generally did not lead to significant staffing shortages.[46] This finding alleviates concerns that mandatory vaccination policies might reduce workforce capacity in critical healthcare environments, affirming the viability of mandates as a strategy to increase vaccine coverage without compromising staff availability.

These findings highlight the importance of mandates in achieving high immunization levels in healthcare settings critical to public health. They support using policy-driven approaches to increase vaccination uptake among healthcare providers, ultimately contributing to safer environments for both patients and staff, especially for those at high risk, such as the elderly and immunocompromised individuals.

Mandate Prohibitions and Legal Challenges

While mandate requirements have been extensively studied, less research has focused on mandate prohibitions and their impact on vaccination coverage rates. Exploring the effects of prohibitions on COVID-19 vaccine uptake, it was found that states with vaccine mandate prohibitions tended to precede lower booster and influenza (flu) vaccination coverage rates, suggesting that prohibition policies may disincentivize

vaccination even for other diseases.[37] This finding suggests that prohibition policies may disincentivize vaccination efforts, potentially creating a ripple effect that discourages vaccination for other diseases beyond COVID-19.

Several studies suggest that mandate prohibitions reflect broader public skepticism toward government intervention in personal health decisions, which can weaken public health campaigns aimed at increasing vaccination.[48,49] Public policies limiting vaccine requirements often emphasize individual choice and autonomy, which can sometimes correlate with lower vaccination uptake compared to policies prioritizing collective health benefits.[24] This cultural emphasis on individual autonomy may contribute to lower overall vaccination coverage rates when mandates are prohibited, as individuals are less likely to feel compelled to vaccinate without policy-driven incentives or requirements.[50]

There are unintended consequences of prohibitive policies, arguing that prohibitions can exacerbate distrust in public health efforts and foster a perception that vaccination is optional rather than essential.[36] This can lead to normalizing non-vaccination behaviors within communities, further lowering uptake rates for COVID-19 and other routine vaccinations, such as those for flu and measles. By positioning vaccination as a personal choice rather than a public responsibility, prohibition policies may undermine the collective immunity needed to protect vulnerable populations, thereby increasing the risk of outbreaks.

Furthermore, states with mandate prohibitions often experience political divides reinforcing vaccination resistance. Research highlights how state political ideology plays a significant role in attitudes toward vaccination policies, with conservative-leaning states more likely to implement prohibitions.[51,52] This political resistance may also translate into lower trust in public health institutions, thereby reducing the effectiveness of vaccination campaigns. As a result, prohibition policies can have a lasting impact on public health infrastructure by diminishing overall trust and participation in immunization programs.

This body of research underscores the potential downside of prohibition policies from a public health perspective. By discouraging vaccine mandates, states may unintentionally promote lower vaccination coverage rates, not only for COVID-19 but also for other critical immunizations. This highlights the importance of carefully considering public health priorities when designing policies that impact vaccination uptake.

Legal discussions also play a critical role in shaping mandate policies. In January of 2022, the U.S. Supreme Court stopped part of the September 2021 Federal Mandate, which said that any company with more than 100 people would need to mandate vaccinations.[53] Additionally, in Biden v. Missouri, the Supreme Court upheld the vaccine mandate for all health care workers who work with CMS, Medicaid, or Medicare.[54] These rulings related to COVID-19 mandates have set precedents that could influence future public health policies.[55] The overview of state-level legal interventions highlights the diverse approaches taken across the U.S[56]. This variation in legal stances further

underscores the importance of understanding how mandate requirements and prohibitions impact public health outcomes differently across states.

Evaluating the Impact of State-Level Vaccine Mandates on Vaccination Coverage Rates

Empirical data from the CDC provide valuable insights into vaccination trends across states.[57] These data will be crucial for examining how policies impacted COVID-19 vaccination coverage rates from September 2021 to September 2022, contributing to a better understanding of the role of mandates in public health. Building on the current literature, this research will fill a critical gap by examining vaccination coverage rate trends across three types of states: those with mandate requirements, those with mandate prohibitions, and those with no specific mandates. This study will focus on policies that impact the adult population and will assess the impact of all three levels of state vaccination mandates by comparing vaccination coverage rates for adults aged 18 and older in states with different mandate types. We will not include mandates related to children, schools, or educational environments. The timeframe for this study is one year, beginning September 1, 2021, and ending on September 7, 2022. By comparing these three groups over this specific time frame, this study aims to assess whether there are significant differences in vaccination coverage trends between states with and without mandates. This approach will provide insights into the influence of state-level policies on adult vaccination coverage rates, contributing to a nuanced understanding of public health policy impacts during health crises.

Summary of Current Problem and Study Relevance

Existing literature highlights the potential of mandates requiring vaccination to increase vaccination coverage rates but also shows the complexity of public reception and legal challenges. There is a gap in comparative studies that analyze the distinct impacts of state-level vaccine mandate requirements, state-level vaccine mandate prohibitions, and states with either minimal or no vaccine mandate policies on COVID-19 vaccination coverage rates. This study addresses this gap by providing a state-level comparative analysis considering these policies' political and social context. This research aims to inform more effective public health policies and strategies for managing infectious diseases by examining how these different approaches influence vaccination behavior.

Chapter III: Methodology

Population and Sample

The study population included adults (18 years and older) across all 50 states and Washington, D.C. (n=51) during the period from September 2021 to September 2022. Census data estimates were used for each state population. These estimates were derived from the state's 2020 census data, with adjustments made for annual changes in birth rates, death rates, and both domestic and international migration. The five territories/affiliates of the U.S., Puerto Rico, Guam, America Samoa, Northern Mariana Islands, and the U.S. Virgin Islands, were not included.

Research Design

This study employed a retrospective, observational design to analyze secondary data. The primary outcome of interest was the cumulative COVID-19 vaccination coverage rates across all U.S. states and Washington, D.C. The primary exposure variable was the type of vaccine mandate implemented in each state, categorized into three groups: 1) states with two or more mandates requiring COVID-19 vaccination, 2) states with prohibitions against COVID-19 vaccine mandates, and 3) states with only the federal mandate and no state mandates or only one state mandate requirement. To evaluate the impact of state-level political environments, two variables were added. The first variable captured the political control of each state—defined by the party affiliation of the governor or mayor and the composition of the legislature or city council. The second was how each state voted for the president in 2020.

The analysis spanned from September 1, 2021, to September 7, 2022. The end date (September 7, 2022) was chosen because vaccination data for September 1–6, 2022, were unavailable due to changes in reporting schedules. In June 2022, the reporting schedule for vaccinations changed from a daily report to a weekly one on Wednesdays. This timeframe was selected to reflect a year from the first federal mandate and the average start date of state mandates.

Data Sources

Data were obtained from four different sources; vaccination counts were from the Immunization Information System (IIS) COVID-19 Vaccinations in the United States Jurisdiction. IIS collected these data from every state from all vaccination partners, including jurisdictional partner clinics, dialysis centers, retail pharmacies, long-term care facilities, Federal Emergency Management Agency (FEMA) and Health Resources and Services Administration (HRSA) partner sites, and federal entity facilities[57]. The second dataset provided the variable for vaccine counts (Series_Complete_18Plus), which reflects the total number of people 18+ with a completed primary series (i.e., have a second dose of a two-dose vaccine or one dose of a single-dose vaccine) based on the jurisdiction where the recipient lives. This was chosen because the number of doses each individual received is not defined in the dataset, and this variable counts only one person per series of doses. Furthermore, using this measure of vaccine counts instead of administered doses was necessary because boosters were deemed necessary due to waning immunity from one's initial series in September 2021, further complicating the number of vaccine doses per person in a state.

The U.S. Census Bureau supplied state and Washington D.C. population estimates for 2021 and 2022, facilitating population-based rate calculations for adults in each location. We used data from the National Conference of State Legislatures (NCSL) to establish the political power of each state and Washington, D.C. It was consolidated to show which political party had power in the state, combining the legislature and governor, as well as the mayor and city council for Washington, D.C. Each state's 2020 electoral college vote was collected from the Federal Election Commission's (FEC) election results, broken down my location. Nebraska and Maine distributed their electoral votes proportionally to their popular vote results and were categorized as such.

State-level vaccine mandate requirements and prohibitions were collected from the CDC's datasets. These data are derived from publicly available state and territorial laws and official policy documents found by the CDC's COVID-19 Mitigation Policy Analysis Unit and the CDC's Center for State, Tribal, Local, and Territorial Support, Public Health Law Program. States' mandates were divided into two groups: prohibitions and requirements[21,22]. States not included in either dataset were identified as having the federal vaccine mandate, which went into effect on September 1, 2021.

Data Analysis and Instruments

This study relied on secondary data sources, so no primary data collection instruments were used. To ensure consistency and accuracy in the datasets, data cleaning and preparation steps were performed using Microsoft Excel and SAS software. All analyses were conducted using SAS® version 9.4 (SAS Institute Inc., Cary, NC).

To identify states with mandate requirements, we began with all states and territories with vaccine mandates starting November 2020 through July 2023 (n=348 mandates). We excluded all territories (n=3 territories and n=43 mandates) and mandates targeting K-12 schools, institutes of higher education (IHE), and school workers (n=53 mandates). The remaining mandates were about congregate facility workers, government workers, healthcare workers, long-term care facilities, patrons of business, and visitors to government (n= 150 mandates). For this study, mandates had to be for vaccinations only, excluding "testing out" exemptions (n=84 mandates), which allowed for people to either be vaccinated or partake in testing at regular intervals to show that they were negative for COVID-19. To assess the impact of mandates, states were required to have at least two mandate requirements to ensure coverage of multiple groups and a broader statewide impact. Three states with only one vaccine mandate requirement were excluded from the analysis (North Carolina, Virginia, and Wisconsin). The final states with two or more mandates were California, Colorado, Connecticut, Washington, D.C., Hawaii, Illinois, Maine, Massachusetts, Nevada, New Jersey, New Mexico, New York, Oregon, Rhode Island, and Washington (n=15 states).

To identify states with vaccine mandate prohibitions, there was a similar cleaning method, beginning with all states with vaccine mandate prohibitions (n=1410 mandates). No territories were in this original dataset needing to be removed. We removed mandates about K-12 Schools, IHE, and school workers (n=557 mandates). To keep the mandates about vaccinations only, those focused on issuing vaccine passports were removed (n=178 mandates). The remaining mandates were about the same groups as the mandate requirements: congregate facility workers, government workers,

healthcare workers, long-term care facilities, patrons of business, and visitors to government (n=551 mandates). All remaining states had more than two mandates, so none were excluded. Virginia had both mandate requirements and mandate prohibitions due to a Governor's change in January 2022. Although Virginia only had one mandate requirement, it was removed from the prohibition group and put into the control group because of the combination of mandates within the study period. The final group of states with mandate prohibitions were Alabama, Arizona, Arkansas, Florida, Georgia, Idaho, Indiana, Iowa, Kansas, Michigan, Mississippi, Missouri, Montana, New Hampshire, North Dakota, Oklahoma, South Carolina, South Dakota, Tennessee, Texas, Utah, West Virginia, and Wyoming (n=23 states).

The final group of states were those with only the federal vaccine mandate, or only one vaccine mandate requirement. These states were Alaska, Delaware, Kentucky, Louisiana, Maryland, Minnesota, North Carolina, Nebraska, Ohio, Pennsylvania, Virginia, Vermont, and Wisconsin (n=13).

State political power was defined as the party that controls the legislature and governor. Nebraska has a unicameral and nonpartisan legislature, so the party in power was determined by the governor and the 2020 presidential election electoral college results. Nebraska's Electoral College votes are split and not required to all be for the same candidate, but in 2020, four of the five electoral votes were Republican. This replaced the political power of the legislature. The political power was determined to be Republican because the governor was Republican, and the majority of the Electoral

College votes were Republican. For Washington D.C., the party of the mayor and the city council were used instead of the legislature and governor.

For the final dataset, for all 51 states and Washington, D.C. the population of adults for 2021 and 2022 were pulled from the Census estimates, the type of mandate for each location, the political power in 2020, and vaccination counts for the two time periods were all combined, using Microsoft Excel and SAS.

To determine the impact of vaccine mandates on vaccination coverage rates, vaccination counts were the outcome, and vaccine mandate was the exposure. Covariates considered were the state's presidential vote for the 2020 election and the state political party in power.

Statistical analyses

Poisson regression was selected as the primary analytical method because it is suitable for count data and estimates vaccination rate ratios (VRR) of vaccinations across states with the three mandate types. To prepare the dataset for Poisson regression, it was converted from a wide format dataset to a long format, creating the variable 'time period' to denote the year (i.e., 2021 or 2022). Each state's adult population was transformed into log(Population) to fit requirements. For the model selection, collinearity was examined for all possible covariates. The 2020 presidential vote was collinear with both the vaccine mandate type and the state political party, so it was removed from the model. This left the model with the following variables: vaccination count (outcome), mandate (exposure), population, time period, and state political power

(Figure 1). Using proc glimmix in SAS, we assessed for effect modification by testing the interaction of state mandate and state political power; it was determined not to be significant and the interaction term was removed. However, because of the known impact of state political power on state vaccination, this was kept in the model as a control variable. Once the model was complete, estimate statements were used with the proc glimmix code to determine the difference between the mandate groups at the two time periods. These comparisons were states with vaccine prohibitions vs. states with no mandate at time 1, states with vaccine prohibitions vs. states with no mandate at time 2, states with vaccine requirements vs. states with no mandate at time 1, states with vaccine requirements vs. states with no mandate at time 2, states with vaccine prohibitions vs. states with vaccine requirements at time 1, and states with vaccine prohibitions vs. states with vaccine requirements at time 2. Additionally, the effect of time periods on the mandates was run, but there was not sufficient data for results.

Chapter IV: Results

Political Influence

Of the 50 states and Washington, D.C., the state political power for 23 states (45.1%) was Republican-controlled, 15 (29.4%) was Democratic-controlled, and 13 (25.5%) was divided between parties (Table 1). Among the 15 states with a vaccine mandate requirement, 13 (86.7%) were Democratic-controlled. Among the states with vaccine mandate prohibitions, 19 (82.6%) were Republican-controlled. States with no mandates showed a more balanced distribution of political power, with 8 (61.5%) having divided political control. Similarly, based on the 2020 Presidential Election results, Democratic-led states overwhelmingly implemented mandate requirements (14/15 states, 93.3%), whereas Republican-led states primarily enacted mandate prohibitions (19/23 states, 82.6%).

Influence of Time

The vaccination coverage rates varied across mandate categories and time periods. During September 2021 (time one), states with mandate requirements had the highest median vaccination coverage rate, 0.71 (IQR 0.67-0.72), while states with mandate prohibitions reported the lowest median rate, 0.55 (IQR 0.51-0.59). By September 2022 (time two), vaccination coverage rates increased across all groups, with state mandate requirements achieving the highest median rate of 0.84 (IQR 0.79-0.87). States with mandate requirements had the highest median population (time one: 3,395,312 (IQR 1,145,427-7,238,538) and time two: 3,393,584 (IQR 1,142,274-7,243,106)) and vaccinated individuals (time one: 2,307,112 (IQR 838,712-5,128,191) and time two:

2,669,939 (IQR 990,746-6,051,061) during both time periods, whereas states with mandate prohibitions had lower medians in both metrics.

Impact of State Mandates, Adjusted for State Political Power

States with vaccine mandate prohibitions during time one had a 9% lower rate of vaccination coverage than in states with no mandates (VRR = 0.91; 95% CI 0.85-0.97, Table 2, Figure 2). Similarly, during time two, states with mandate prohibitions had an 8% lower rate of vaccination coverage than states with no mandates (VRR = 0.92; 95% CI 0.86- 0.98). States with mandates requirements during time one had vaccination coverage that was 10% higher than states with no mandates (VRR = 1.10; 95% CI 1.01-1.20). This continued into time two; states with mandate requirements had a vaccination coverage rate that was 11% higher than states with no mandates (VRR = 1.11; 95% CI 1.02-1.22).

When comparing states with mandate prohibitions to those states with mandate requirements, states with mandate prohibitions had consistently lower vaccination coverage rates. During time one, states with mandate prohibitions had a vaccination coverage rate that was 18% lower than states with mandate requirements (VRR = 0.82; 95% CI 0.75-0.90). Similarly, during time two, states with mandate prohibitions had a vaccination coverage rate 17% lower than states with mandate requirements (VRR = 0.83; 95% CI 0.75-0.91). These results emphasize the positive impact of mandate requirements on improving vaccination coverage rates compared to mandate prohibitions.

State political control in 2020 did not significantly impact vaccination coverage rates. Democratic-controlled states had a non-statistically significant higher vaccination coverage rate than Republican-controlled states (VRR = 1.04; 95% CI 0.99-1.09). Similarly, states with divided control showed no difference in vaccination coverage rates relative to Republican-controlled states (VRR = 1.06; 95% CI 1.03, 1.10). These findings suggest that the type of vaccine mandate and the timing of implementation had a more substantial effect on vaccination coverage rates than political control.

Chapter V: Conclusions, Implications, and Recommendations

Summary of Study

This study examined the impact of state-level COVID-19 vaccination mandate requirements, mandate prohibitions, and states with no mandates on adult vaccination coverage rates in the United States from September 2021 to September 2022. Using a retrospective observational design and Poisson regression analysis, the study explored vaccination coverage rates across three policy categories—mandate requirements, mandate prohibitions, and no mandates (or minimal mandates)—while adjusting for state political control. The findings revealed that states with mandate requirements had significantly higher vaccination coverage rates, while states with mandate prohibitions consistently had lower rates. Time periods also played a critical role, with vaccination coverage rates improving significantly overall at time two. However, political control had no statistically significant effect on vaccination coverage rates, suggesting that mandates and time periods were the most influential factors.

Mandate Requirements and Mandate Prohibitions

The study found that states with mandate requirements consistently had the highest vaccination coverage rates, while states with mandate prohibitions had the lowest rates. For instance, during time one (September 2021), states with mandate prohibitions had a vaccination coverage rate 18% lower than states with mandate requirements. This pattern persisted during time two (September 2022), highlighting the long-term effectiveness of mandate requirements. These findings align with prior research

showing that mandates increase compliance potentially by reducing barriers such as hesitancy, misinformation, and logistical challenges[34,58]. Mandates can help establish a social norm and reinforce the perception that vaccination is a collective responsibility[59]. However, mandates are not without challenges, as they may face public resistance, particularly in states with political or ideological opposition to centralized public health measures[60].

Temporal Trends in Vaccination Coverage Rates

Vaccination coverage rates improved across all groups from September 2021 to September 2022, with the greatest gains observed in states with mandates. For example, vaccination coverage rates in states with no mandates increased from a median of 0.64 (IQR 0.59-0.67) during time one to a median of 0.75 (IQR 0.72-0.79) during time two. This improvement likely reflects expanded vaccine availability, public health campaigns, and evolving public attitudes. National campaigns encouraging boosters and clearer messaging may have played a critical role during this time[61–63]. This finding underscores the importance of sustained public health efforts and the adaptability of policies to maintain progress during prolonged crises.

Role of State Political Control

State political control (Republican, Democratic, or Divided) did not significantly influence vaccination coverage rates after accounting for mandates and time periods. Not all states with mandate prohibitions held state Republican power; seven of the 23 prohibition states were either Democrat or divided in state power. This contrasts with

prior research suggesting a stronger association between political ideology and vaccine uptake.[51,52] This finding may indicate that the complexity of vaccination decision-making, rather than the state political climate, drives vaccination behavior when implemented.

Limitations

Data Availability and Potential Unmeasured Confounders

When building the dataset for this thesis, several covariates could not be collected and added to the dataset. These include information about jobs that require vaccination to maintain employment, especially those working in the healthcare system. Healthcare workers were amongst the first to have access to the COVID-19 vaccines and were required to be vaccinated. Additionally, the causes of people not being vaccinated, such as personal health and beliefs, are not readily available. Another important variable to evaluate is the impact of the federal vaccine mandate. This included all people working for the federal government and those working in a healthcare setting that received CMS funding.

The IIS dataset with all vaccination counts has limitations because of the methods used to organize the state vaccine count data. In early 2020, vaccines were not uniformly available across the U.S., and evidence suggests that some people would cross state lines to get a vaccine before it was available in their home state. Given that these individuals were not required to identify their home state, their vaccination would not get counted in the home states; instead, it would be in the state they visited for their vaccination. This also includes people who moved into another state during the time between doses;

their doses would be accounted for in both states. This can cause an underestimation of the count of people who finished their initial COVID-19 series in each state.

Although we attempted to cover the government authority enacting a mandate in this study, we could not due to the complications of identifying the source of a mandate. States would have mandates originating from their Department of Public Health and Secretary of State, not just from their governor. Identifying if these should be grouped together or into different categories beyond executive or legislative could be helpful for future research considerations.

Unknown and Unmeasured Confounders

A notable limitation of this study is the potential influence of unknown and unmeasured confounders that may have affected vaccination coverage rates. This analysis did not directly measure critical drivers of vaccination behavior, such as individual motivations, access to healthcare, and social networks. Additionally, intrastate cultural and demographic variations—such as rural versus urban differences, socioeconomic disparities, and local political dynamics—may have played a significant role in shaping vaccine uptake but were beyond the scope of this study. These unmeasured factors could vary substantially even within states, potentially influencing the observed associations between state-level policies and vaccination outcomes. As a result, the findings should be interpreted with caution, acknowledging that these confounders may contribute to unexplained variability in vaccination coverage rates across states.

Interpretation of the No Mandate Group

The no mandate group, which served as the reference category, includes states with either no state vaccine mandates or only one mandate requirement. We decided to combine states without mandates, and those with only one mandate requirement were decided upon to help keep the other two categories as homogenous as possible. States with only one vaccine mandate requirement targeted only one group of people within their state to become vaccinated, compared to other states that would cover groups such as workers in congregate facility locations and visitors to government buildings. Therefore, they would not have as broad an effect as those states with mandates covering several groups of people. As a result, this requires cautious interpretation due to the differences within this category. For instance, a state with no mandates may differ significantly from one with a limited mandate, yet both were grouped for analytical purposes. Further research is needed to disentangle the unique effects of these subgroups.

Implications and Recommendations

The findings from this study have significant implications for public health practice and policy, particularly in the context of managing infectious disease outbreaks and pandemics like COVID-19. This study suggests that vaccine mandate requirements were effective tools for increasing vaccination coverage rates. Policymakers could consider incorporating mandates into broader public health strategies for future pandemics or public health crises. By creating a social norm around vaccination and reducing hesitancy, mandate requirements can play a critical role in achieving higher vaccine coverage, which is essential for population immunity and preventing severe disease.

However, mandate requirements alone are not sufficient to address disparities in vaccination uptake. The results underscore the need for equity-focused strategies to reduce barriers in underserved communities, where structural inequities such as limited access to healthcare or mistrust in public health systems persist. Tailored communication and outreach efforts, including partnerships with community leaders and culturally appropriate messaging, are vital to ensuring that all populations benefit from public health interventions. Additionally, clear and consistent public health messaging is critical for maximizing compliance and countering misinformation. Transparent communication strategies that emphasize the safety, efficacy, and communal benefits of vaccination are necessary to build public trust and reduce resistance to mandates.

To enhance the effectiveness of future vaccination campaigns, several recommendations emerge from this study. First, policymakers should consider expanding the use of vaccine mandate requirements in critical sectors such as healthcare and public services while simultaneously addressing public concerns to minimize resistance. Mandate requirements must be accompanied by robust public education campaigns to ensure they are understood and accepted by the public. Second, targeted interventions are needed to address equity issues in vaccine access and uptake. Programs designed to overcome logistical barriers, such as mobile vaccination clinics or subsidies for vaccine-related costs, could help close gaps in underserved communities. Partnerships with trusted community organizations can also foster greater trust and participation. There needs to be continued transparency about the evidence supporting vaccine mandates and vaccine schedules. Finally, longitudinal studies are essential to assess the long-term

impacts of vaccine mandate requirements and prohibitions on both vaccination coverage rates and public trust in health systems. Such studies could provide insights into whether both types of mandates lead to sustained behavioral changes or if their effects diminish over time.

In summary, the findings of this study offer insights for future public health interventions. Vaccine mandate requirements are a powerful tool for increasing uptake, but they must be implemented with attention to equity and public trust. By combining mandate requirements with targeted outreach and continuous evaluation, policymakers can build resilient public health systems better prepared to mitigate future health emergencies.

Conclusion

This study demonstrates the role of state-level vaccination mandate requirements in increasing vaccination coverage rates during a public health crisis. Mandate requirements consistently outperformed mandate prohibition policies over time in their effectiveness for fostering vaccine uptake. Political control had no significant effect on outcomes, emphasizing the overriding importance of mandate requirements driving vaccination coverage. These findings offer actionable insights for policymakers and public health professionals, supporting the appropriate adoption of mandates to enhance population immunity to vaccine-preventable outbreaks and epidemics.

Tables and Figures

Table 1

Variable	Overall (n=51)	States with Mandate Requirements (n=15)	States with Mandate Prohibitions (n=23)	States with No Mandates (n=13)
State Political Power No. (%)				
Democrat	15 (29.41%)	13 (86.67%)	0 (0%)	2 (15.38%)
Republican	23 (45.10%)	1 (6.67%)	19 (82.61%)	3 (23.08%)
Divided	13 (25.49%)	1 (6.67%)	4 (17.39%)	8 (61.54%)
2020 Presidential Election No. (%)				
Democrat	25 (49.02%)	14 (93.33%)	4 (17.39%)	7 (53.85%)
Republican	24 (47.06%)	0 (0%)	19 (82.61%)	5 (38.46%)
Split Between Two Parties	2 (3.92%)	1 (6.67%)	0 (0%)	1 (7.69%)
Vaccination Coverage Rate, median (IQR)				
September 2021	0.613 (IQR 0.546-0.679)	0.708 (IQR 0.67-0.728)	0.546 (IQR 0.508-0.595)	0.641 (IQR 0.589-0.67)
September 2022	0.734 (IQR 0.665-0.811)	0.835 (IQR 0.79-0.871)	0.665 (IQR 0.64-0.724)	0.75 (IQR 0.718-0.788)
Population, median (IQR)				
September 2021	3485367 (IQR 1426780-6059535)	3395312 (IQR 1145427-7238538)	2460715 (IQR 1426780-5407790)	4398718 (IQR 1479248-6762144)
September 2022	3492357 (IQR 1419116-6118479)	3393584 (IQR 1142274-7243106)	2466127 (IQR 1419116-5484281)	4404797 (IQR 1485736-6790798)
Number of People Vaccinated, median (IQR)				
September 2021	2066526 (IQR 768452-4248546)	2307112 (IQR 838712-5128191)	1548966 (IQR 700487-2961264)	2947597 (IQR 945861-4556333)
September 2022	2374708 (IQR 984662-4965075)	2669939 (IQR 990746-6051061)	1789011 (IQR 892503-3477219)	3469091 (IQR 1106265-5572546)

Table 2

Incidence Rate Ratios Between State-Level Mandate Groups, 2021 and 2022			
Year	**Comparison**	**VRR (95% CI)**	**p-value**
2021	States with Mandate Prohibitions vs. States with No Mandates	0.91 (0.85-0.97)	0.0051
2022	States with Mandate Prohibitions vs. States with No Mandates	0.92 (0.86-0.98)	0.0169
2021	States with Mandate Requirements vs. States with No Mandates	1.10(1.01-1.20)	0.0274
2022	States with Mandate Requirements vs. States with No Mandates	1.11 (1.02-1.22)	0.0166
2021	States with Mandate Prohibitions vs. States with Mandate Requirements	0.82 (0.75-0.90)	0.0002
2022	States with Mandate Prohibitions vs. States with Mandate Requirements	0.83 (0.75-0.91)	0.0002

Figure 1

Directed Acyclic Graph (DAG) selection of model variables

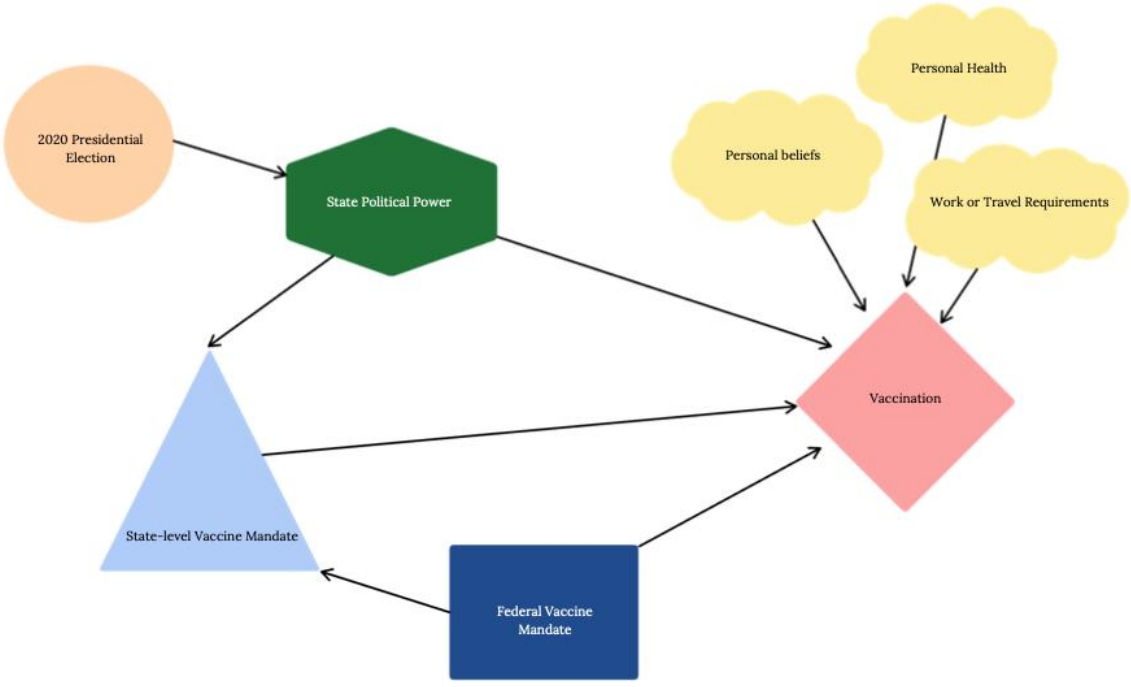
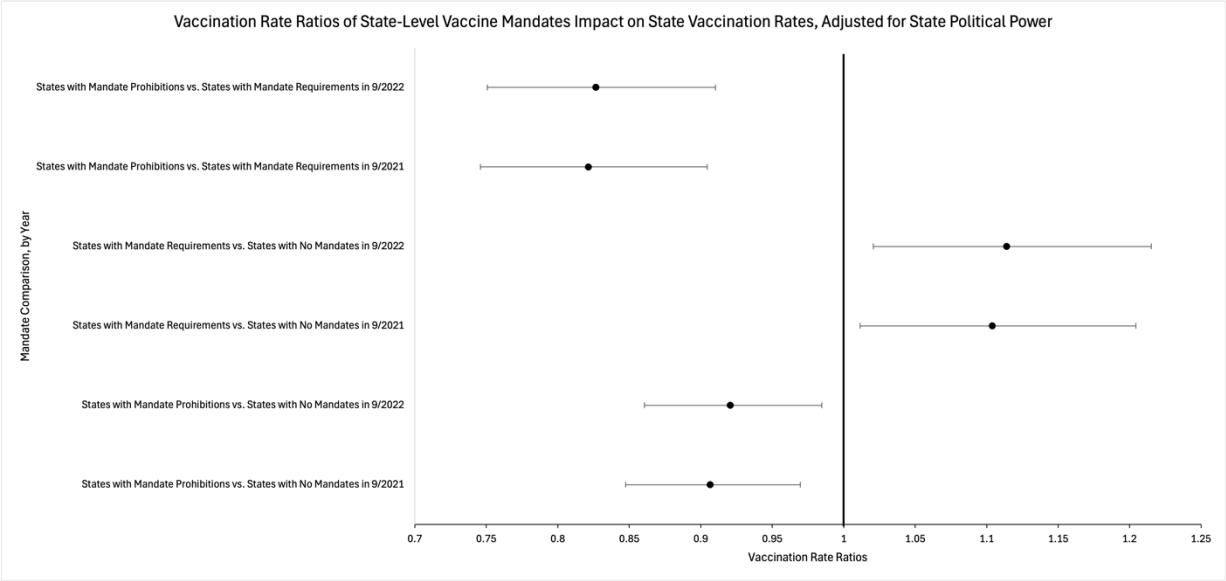


Figure 2


Vaccination Rate Ratios of State-Level Vaccine Mandates Impact on State Vaccination Rates, Adjusted for State Political Power
States with Mandate Prohibitions vs. States with Mandate Requirements in 9/2022
States with Mandate Prohibitions vs. States with Mandate Requirements in 9/2021
States with Mandate Requirements vs. States with No Mandates in 9/2022
States with Mandate Requirements vs. States with No Mandates in 9/2021
States with Mandate Prohibitions vs. States with No Mandates in 9/2022
States with Mandate Prohibitions vs. States with No Mandates in 9/2021
Mandate Comparison, by Year
0.7
0.75
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
1.25
Vaccination Rate Ratios

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