Distribution Agreement

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

Signature:

_____ 04/25/2024

Jiyeon Lee

Exploring Immigrant Disparities: The Influence of Immigrant Status on COVID-19 Vaccination in the United States

By

Jiyeon Lee
MPH

Hubert Department of Global Health

Unjali Gujral
Committee Chair

Exploring Immigrant Disparities: The Influence of Immigrant Status on COVID-19 Vaccination in the United States

By

Jiyeon Lee
Bachelor of Science
University of California, Irvine
2019

Thesis Committee Chair: Unjali Gujral, MPH, PhD

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Global Health
2024

Abstract

Exploring Immigrant Disparities: The Influence of Immigrant Status on COVID-19 Vaccination in the United States

By Jiyeon Lee

Background:

In the United States, despite the substantial number of immigrants, detailed research into their health outcomes is limited. The COVID-19 pandemic has further amplified health disparities among this group. Studies often combine diverse immigrant groups: refugees, migrants, naturalized, and undocumented individuals into a single category of 'immigrants', failing to acknowledge the unique challenges and disparities each subgroup faces. Our study seeks to address these gaps by analyzing the 2022 California Health Interview Survey (CHIS) to discover the effects of immigration status on COVID-19 vaccination rates. We expand our research beyond commonly studied variables like language and culture, to obtain a further comprehensive understanding of vaccine decision.

Method:

Secondary data analysis was conducted from the CHIS adult sample. 21,463 individuals were categorized into three groups: US-born (n =15,866), naturalized (n=3,993), and non-US citizens (n=1,604). The polytomous logistic regression was applied to evaluate and control demographic and risk-reduction behavioral characteristics.

Result:

Among 21,463 individuals, 93.5% of naturalized citizens, 88.7% of non-US citizens, and 89.5% of US-born citizens were fully vaccinated. Logistic regression revealed that naturalized citizens were 1.41 times more likely to be vaccinated compared to US-born citizens (aOR: 1.41; CI: 1.19-1.67) with demographic adjustment. Controlling for behavioral factors, naturalized citizens were 51% more likely to vaccinate (CI: 1.31 – 1.74) and 37% more likely (aOR: 1.37; CI: 1.15-1.64) with controlling for all variables. Non-US citizens exhibited varying likelihoods with no statistical significance. A positive correlation was found between increasing age and vaccination likelihood, with oldest age twice more likely to vaccinate (aOR:2.08; CI:1.54-2.82). Decreased English proficiency reduced vaccination likelihood, with ratios ranging from 1.05 to 0.60 as proficiency levels declined. Risk-reduction behaviors was associated with a greater likelihood of vaccination.

Conclusion:

This preliminary study is one of the few that analyzes COVID-19 vaccination behaviors across immigrant subgroups, providing comprehensive insights into the complex dynamics that shape vaccination. This study highlights the need for public health research to address the unique barriers tailored specifically to this diverse community. Developing interventions that cater specifically to different immigrant subgroups is essential for bridging healthcare gaps and promoting health equity.

Exploring Immigrant Disparities: The Influence of Immigrant Status on COVID-19 Vaccination in the United States

By

Jiyeon Lee
Bachelor of Science
University of California, Irvine
2019

Thesis Committee Chair: Unjali Gujral, MPH, PhD

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Global Health
2024

Acknowledgements

I would like to express my gratitude to my advisor, Dr. Unjali Gujral, for her invaluable mentorship and support throughout this thesis. Thank you for your patience and flexibility as constant modifications were made. Your guidance has been instrumental in my growth as a researcher.

Special thanks to all my professors, advisors, and my supervisor for their guidance and encouragement throughout my time at Rollins. I also want to extend my thanks to all my friends and peers who have shared this incredible journey at Rollins School of Public Health. The sleepless study nights and figuring out this journey together could not have been done without any one of you.

I extend my heartfelt appreciation to all my friends, both back home in California and here in Georgia, for standing by me and providing support whenever and wherever I needed it. Special love and thanks to all my friends who shared their pets with me. Their love and support were greatly appreciated during stressful times. I am also grateful to all my church families for their prayers and encouragement.

I am deeply thankful to my roommates, Manika, Elora, and our beloved Casper, for their constant emotional support. You guys have been my chaotic new family, my new love and support. Lastly, I extend my deepest gratitude to my family, Hyera, Kangmyoung, Hyejung, and Jae, for their unwavering support throughout my journey at Rollins, especially my brother Jae, who supported me with patience and love even during my 2 AM phone calls.

Table of Contents

Chapter 1. Introduction

The immigrant population exceeds 49.5 million in the United States, constituting approximately a quarter of the national population according to the Census Bureau (Camarota & Zeigler, 2023; Esterline & Batalova, 2022) (Of these, 21.2 million immigrants are non-U.S. citizens, while an additional 24.2 million are naturalized citizens (KFF, 2023). Additionally, an estimated 10.7 million undocumented immigrants accounted for 3.3% of the total U.S. population in 2016 (Rafiqul et al., 2021). Despite the substantial number of immigrants currently living in the United States, a notable gap persists in research focusing on the intricate health disparities experienced by this population.

Although the United States is home to the largest immigrant population globally, immigrant health remains an area characterized by limited resources and data. Existing studies on immigrant health primarily focuses on healthcare access, highlighting language, cultural, and socioeconomic factors as predominant barriers (National Academies of Sciences, 2018). The recent COVID-19 pandemic has further magnified the health disparities within this population (Hill et al., 2021; Pedraza et al., 2022; Siddiq et al., 2024). Immigrants were often excluded from the pandemic response plans due to insufficient data, especially concerning immigrant statuses (International Organization for Migration, 2023). Only three countries – Thailand, Papua New Guinea, and the Maldives – had previously included non-citizens in their pandemic preparedness plan for influenza (Wickramage et al., 2018).

Globally, immigrants have exhibited a heightened risk of COVID-19 infection, morbidity, and mortality, yet specific data detailing these impacts remain scare (OECD, 2022; Page et al., 2022). In 2020, immigrants accounted for 43.5% of all COVID-19 cases in Canada, with lower testing rate but higher positivity (Guttmann et al., 2020; Sundaram et al., 2021). In Norway, the proportion of positive cases among immigrants rose from 19% to 42% within a single month

(Hayward et al., 2021). In the United States, foreign-born individuals were positively associated with COVID-19 incidences. Non-English-speaking immigrants were tested 5.6% less frequently yet were 18.6% more likely to test positive (Kim et al., 2020; Strully et al., 2021).

Prior to the COVID-19 pandemic, immigrants in the United States were identified as having low levels of vaccine uptake (Daniels et al., 2022). For instance, studies indicate that immigrants are half as often vaccinated compared to non-immigrant (Jang & Kang, 2021; Rojas-Venegas et al., 2022). Despite positive attitudes toward routine vaccination, suboptimal vaccination rates persist among this group. Immigrant groups were vaccinated 38% less for HPV vaccine, 25 % less for influenza, and 41% less for hep B vaccine compared to US-born citizens (Daniels et al., 2022).

Newly arrived immigrants often prioritize employment and accommodation over healthcare due to unfamiliarity with the American healthcare system. Acculturation, a paramount concern for immigrants, has been associated with poorer health outcomes and an increased prevalence of cardiometabolic risk factors (Commodore-Mensah et al., 2016; Kolker & Heisler, 2022). Prevalence of diabetes was significantly higher among the least acculturated compared to the most acculturated Hispanics by 2.49 times (Kandula et al., 2008). A study in Germany indicated that less acculturated immigrants are 2.74 times more likely to have an incomplete hepatitis B vaccination series (Mikolajczyk et al., 2008). Incomplete vaccination was associated with shorter length of acculturation. Infleunza vaccine coverage among recent immigrants had coverage rate of 0.45, which increased to 0.87 for long-term immigrant (≥ 10 years). In western Europe, the coverage was 0.37 for recent immigrant and 1.07 for long term immigrants (Fabiani et al., 2016). Despite the high number of undocumented immigrants in the U.S., there is a significant lack of large-scale data regarding their vaccine intentions (Sudhinaraset et al., 2022).

Language and cultural differences, coupled with a lack of familiarity with preventive care and fear and distrust of the healthcare system, can severely impair access to appropriate healthcare services (Pottie et al., 2011). Many studies have revealed that reduced vaccination uptake often occurs among individuals with migrant backgrounds and those who speak a language other than English at home (Abdi et al., 2021). As immigrants become more acclimatized to the American healthcare system over time, relationships with primary care physicians are established, and a lifestyle conducive to considerations beyond day-to-day subsistence is cultivated.

There are multiple gaps that hinders from a comprehensive understanding of the factors influencing immigrants' vaccine decisions especially for COVID-19. Hence, there is a critical need to conduct further research into the various factors that may influence immigrants and their health-related decisions.

In this study, we categorized the covariates into demographic and behavioral factors. By categorizing covariates, we aimed to dissect the direct and indirect effects on vaccination (Fig. 1). The categorization of covariates allowed us to control for potential confounders and clarify the relationships between immigrant status and its influence on vaccination. Demographic factors, including age and diabetic status, were selected due to their significant associations with COVID-19.

Age has been associated with a higher risk of illness from COVID-19. Individuals over the age of 65 accounted for more than 81% of COVID-19 deaths in the United States (CDC, 2023b). Studies have shown that individuals older than 50 have a 15.4-fold significantly increased risk of mortality from COVID-19, with those over 65 having 95 times increased risk of mortality than those aged 18 – 29 (Biswas et al., 2020; CDC, 2023b). Age is also a well-established factor in vaccine effectiveness and uptake. The likelihood of receiving an influenzas

vaccine increased 1.01 with age (Takayama et al., 2012). Similarly, diabetes has been significantly associated with COVID-19 severity and vaccine effectiveness. Individuals with type 2 or type 1 diabetes have an increased vulnerability to severe illness from COVID-19. Those with type 1 diabetes were 3.9 times for likely to be hospitalized and 3.4 times more likely to experience severe illness from COVID-19 (Pal et al., 2021).

Demographic factors, including age and diabetic status, may exert a direct influence on vaccination status (Fig. 1). In contrast, length of residency and risk reduction behaviors, i.e. adherence to guidelines and wearing face masks were contemplated as a potential mediator. The length of residency might influence an immigrant's understanding of guidelines or the source of information. The unfamiliarity of a new country could influence immigrants risk reduction behavior, thus, impacting vaccination. The immigrant status was theorized to exert both direct and indirect influence on vaccination.

Despite numerous studies on COVID-19 vaccine uptake, there remains a substantial gap in understanding its impact among immigrants. Data on COVID-19 outcomes stratified by immigration status continues to be sparse. There is lack of comprehensive overview of the extent to which migrants, including refugees, asylum seekers, labor migrants, and undocumented migrants in different high income countries have been impacted by COVID-19, and their specific risk factors (Batalova, 2024; Hayward et al., 2021). The ultimate impact of immigrant status on vaccination rate is yet to be determined. Therefore, this study seeks to understand the potential influence of varying immigrant status in the United States on the COVID-19 vaccination status.

Chapter 2: Literature Review

2.1 Classification and Diversity of Immigrant Population

Migration or immigration, the process of moving from one country to another, has a history dating back thousands of years. This concept of migration dates back to Azerbaijan 10,000 years ago, depicting one of the first movements of humans (Douglas et al., 2019). However, the terminology surrounding immigrant varies significantly across global contexts and academic disciplines. The terms “refugee”, “immigrant”, or “migrant” are often used interchangeably or grouped under one category known as RIM – refugee, immigrant, migrants – community (CDC, 2022) (Hampshire et al., 2019). Defining who counts as immigrant remains a challenge due to these diverse and sometimes ambiguous term.

Technical definitions and categories of immigrants continue to remain unclear. RIM as an umbrella term is not defined under any international law (International Organization for Migration, 2019). There is currently no consensus on immigrant status or set definition. Terms or status like short-term immigrant, asylum seeker, migrants, refugees, undocumented migrants, illegal immigrant, naturalized immigrant, trafficked individuals, aliens, permanent resident, and foreign individuals are grouped under this one large umbrella term of immigrant or RIM (Anderson & Blinder, 2024; Gimeno-Feliu et al., 2019; World Health Organization, 2018). The International Organization for Migration (IOM) defines an immigrant as a non-national individual moving to a country with the goal of settlement (Perruchoud & Redpath-Cross, 2011). Others define immigrant as individuals who establish new residence different from their origin, a relatively permanent movement, or individuals moving across international borders (Gimeno-Feliu et al., 2019).

Immigrants are far from homogenous, differing in characteristics such as migration motives (e.g., work, political asylum, family reunification), status (e.g., legal, undocumented, naturalized), length of stay, or whether the movement was voluntary or involuntary (International Organization for Migration, 2019). The term "immigrant" as an umbrella term overlooks the multigenerational structure and cultural heritage of many migrant families. In addition, the impact of different groups in this population on health greatly differs. A study revealed that the definition of immigrant status based on place of birth or nationality impacts mortality (Gimeno-Feliu et al., 2019). The different ways immigrant status are classified impacts study outcomes and disparities these populations face. It has been argued in the past that these terminologies in research needs to be clarified, as the definition used when interpreting and comparing results in studies will differ (Loue & Bunce, 1999). Despite these varied definitions, characteristics, and impact, different groups of immigrants continue to be grouped together.

2.2 Significance of Vaccination

2.2.1 Vaccines in General

Vaccines are one of the most effective health intervention tools for disease prevention, saving millions of lives each year. Vaccination prevents 3.5 to 5 million deaths annually from vaccine preventable diseases such as tetanus, influenza, and measles, while 750,000 children are saved from disability (Ehreth, 2003; WHO, n.d.). The impact of vaccines extends far beyond individual health benefits. They have played a pivotal role in eradicating diseases and controlling outbreaks. Vaccines reduced the impact of diseases that were once common causes of harm or death among infants, children, and adults (CDC, 2022). Throughout history, vaccines have eradicated smallpox, eliminated wild polio, and eliminated Haemophilus influenza type b. Maintaining a 95% vaccination rate for MMR vaccine would completely halt measle

transmissions (NHS, 2023). Vaccination has not only prevented widespread suffering but has also proven to be one of the most cost-effective healthcare investments. The eradication of smallpox alone has yielded a global savings exceeding US $2 billion annually (Ehreth, 2003).

Influenza leads to an estimated 226,000 hospitalizations and 36,000 deaths annually in the United States. A study revealed that influenza vaccination leads to 13–44% fewer healthcare visits, 18–45% fewer lost work days, and 18–28% fewer work days with reduced effectiveness due to illness (C. J. Lin et al., 2010). Even though vaccine efficacy varies for each virus, with influenza vaccines demonstrating 40-46% efficacy, hepatitis B vaccines close to 100%, and HPV vaccines also close to 100%, vaccination greatly impacts the society. (CDC, 2021, 2023a; WHO, 2024)

Despite the significant benefits of vaccination, vaccine hesitancy continues to exist particularly among immigrant populations. A study conducted in Scotland revealed that 37% of Polish families declined the influenza vaccine for their children, showcasing differences in vaccination rates between immigrant and non-immigrant populations. Specifically, White British children had a 71% vaccination rate against influenza, while Polish immigrant children were vaccinated at a rate of 25%. Similarly, a study exploring parental attitudes toward the HPV vaccine among UK-based immigrant parents indicated widespread reluctance. 35% of Lantin immigrant mothers revealed HPV vaccine hesitancy for their children in the US (Tankwanchi et al., 2021).

2.2.2 COVID-19 Vaccines

The emergence of the COVID-19 pandemic highlighted the critical importance of vaccines in controlling infectious diseases. Studies have estimated that COVID-19 vaccinations prevented millions of deaths globally within the first year of distribution, resulting in 63%

reduction in total death globally (Watson et al., 2022). The mRNA vaccines have shown remarkable effectiveness against COVID-19 infection and its severe forms with over 90% efficacy against infection. Pfizer-BioNTech with 95% efficacy, followed by Moderna (94%), and Sputnik V (92%) provided effective protection against severe illness, hospitalization, and death (Chirico et al., 2022).

The impact of COVID-19 vaccines extends beyond individual protection to community and global health. Studies have estimated that COVID-19 vaccine greatly reduced hospitalizations, ICU admissions, and deaths related to the virus. Hospitalization rates were reduced by 63.5%, ICU admission by 65.6%, and deaths by 69.3% (Moghadas et al., 2021).

The significant impact of COVID-19 vaccine is further highlighted by its impact globally. It was estimated that COVID-19 vaccine prevented 14.4 million deaths in 185 countries within one year. The number of estimated averted death increased to 19.8 million when excess death were considered as an estimate (Watson et al., 2022). Notably, COVID-19 vaccines have been instrumental in averting millions of deaths globally, demonstrating their pivotal role in pandemic control.

2.3 COVID-19 Vaccination Rate

With the significance of vaccine efficacy and its impact, the actual rate of COVID-19 vaccination has varied among immigrants and non-immigrants. Globally, more than 5.55 billion individuals (72.3%) have received at least one dose of COVID-19 vaccine worldwide. Notably, Macau had 99% of the population vaccinated with at least one dose. United States had 80% of the population vaccinated with at least one dose and 68% of the population fully vaccinated. Least vaccinated country was Burundi with 0.3% of the population vaccinated (Holder, 2021).

Observing specifically at citizens of the respective countries, non-immigrant adults, born citizens of their countries have revealed varying levels of COVID vaccination rate. The highest rate of vaccination was observed in Ecuadorian (97%), then Malaysian (94.3%), and Indonesian (93.3%) citizens. Compared to these countries and their citizens, lowest rates of vaccinations were discovered in Kuwaiti (23.6%), Jordanian (28.4%), and Italian (53.7%) citizens. At the time of this study, US was also one of the countries with lower vaccination rate for US-born citizens (56.9%) (Sallam, 2021). Among Canadian citizens, vaccination coverage increased substantially in older age categories; 70.9% - 73.5% of 12-49 years old were vaccinated, which increased to 86.3% for 75 years and above having received at least one dose (MacDonald et al., 2022).

In contrast, immigrants have exhibited notable vaccine hesitancy and lower vaccination rates than the overall population worldwide. Studies revealed that one-quarter of immigrants expressed some degree of hesitancy for COVID vaccination in Sweden (Svallfors et al., 2023). Immigrants in Canada revealed having two-time greater odds of health concerns, anticipated stigma, and vaccine hesitancy than Canadian-born citizens. The overall vaccine hesitancy among immigrants was estimated at 16.9% in Canada (S. Lin, 2022).

Vaccination coverage among immigrants also varied by age and time of migration. Immigrants younger than 50 generally exhibited higher vaccination rate (78.2%) than non-immigrants (76%), while immigrants over 50 generally had lower coverage. Specifically, among immigrants under 50, those who migrated within the past 20 years had higher vaccination rate (70.6% - 82.2%) than those who settled more than 20 years ago (72.1% - 77.6%). However, among older immigrants (50 or older), those who migrated within the past 20 years had lower coverage (49.7% - 78.5%) than those who migrated more than 20 years ago (70.5% - 84%)

(MacDonald et al., 2022). During the initial phase of the COVID-19 vaccination program, immigrants in Europe tended to have lower vaccination uptake as well (Larsson et al., 2022).

These disparities in vaccine acceptance and coverage between immigrants and non-immigrants highlight the need for targeted efforts to address vaccine hesitancy and improve access among immigrant communities.

2.4 COVID-19 Vaccination among Immigrants in the US

Studies assessing the likelihood of COVID-19 vaccination among immigrants in the U.S. have revealed important insights into vaccine acceptance. However, there remains a notable gap in research focusing on actual vaccination rates among immigrant populations.

A study that surveyed refugees in the US discovered that over a third reported vaccine hesitancy for COVID-19. Among those who initially intended to get vaccinated, nearly 1 in 5 reported changing their minds (Shaw et al., 2022). Immigrants are less likely to have complete vaccine series compared to non-immigrants. Various factors associated with incomplete vaccination include mistrust, language barrier, healthcare insurance, and concerns for vaccine safety (Mapouka et al., 2022).

There are limited existing data on the actual completed COVID-19 vaccination rates among immigrants. The few numbers of data become more scarce particularly for undocumented immigrants. Undocumented individuals often face barriers accessing healthcare systems and thus are at an increased risk (Matlin et al., 2022). Studies revealed that undocumented immigrants were 50% less vaccinated than the general population in the US (Demeke et al., 2022).
The under-immunization of Refugee-Immigrant-Migrant (RIM) communities has been highlighted in many research, indicating lower vaccination rates compared to the U.S.-born citizens (Daniels et al., 2022). Yet, the lack of research and data on the specific vaccination rates

among this populations continue to remain unclear. These findings further underscore the need to research the impact of immigrant status on vaccine uptake.

The significance of COVID-19 vaccine uptake among immigrants remains a critical yet understudied area. Despite numerous studies on COVID-19 vaccine uptake, gaps persist in understanding its impact among immigrant populations. Data on COVID-19 outcomes stratified by immigration status is limited, leaving a lack of comprehensive overview of how different groups of immigrants may be influenced. The impact of immigrant status on vaccination rates is yet to be fully understood. Therefore, this study seeks to address these gaps by observing the potential influence of varying immigrant statuses in the United States on COVID-19 vaccination status. We will examine factors that may influence COVID-19 vaccination rates to understand the relationships between vaccination status and immigrant status. Our aim is to provide insights into the decision-making processes of different immigrant groups regarding COVID-19 vaccination. This research will contribute to a deeper understanding of vaccine uptake disparities among immigrant communities and shed light on the impact of immigrant status on COVID-19 vaccination rates in the United States.

Chapter 3: Methods

3.1 Data Source and Study population

The dataset used for this study is the California Health Interview Survey (CHIS), a comprehensive annual health survey led by University of California, Los Angeles. CHIS serves as a significant resource for information on the health and healthcare needs of California's diverse population. The survey is a leading source of data and one of the nation's most extensive health surveys. The primary objective of CHIS is to ultimately improve the health outcomes of Californians.

In 2022, CHIS conducted interviews with over 200,000 households, addressing over 100 health-related topics. The primary methods of data collection were web-based interviews, accounting for 90% of adult responses. To ensure inclusivity, the surveys were available in six languages: English, Spanish, Chinese (Mandarin and Cantonese), Vietnamese, Korean, and Tagalog.

For the purposes of this study, we utilized the 2022 adult (age ≥ 18) sample collected between March 2021 and November 2022 from CHIS. From the initial dataset of 21,463 individuals, we categorized the population into three groups: US-born citizens, naturalized citizens, and non-US citizens.

Our final analytic sample was comprised of 15,866 US-born citizens, 3,993 naturalized citizens, and 1,604 non-US citizens. We categorized the immigrant sample into naturalized citizen and non-US citizen to allow for comparisons and specific analysis of the immigrant population. The immigrant sample was limited to naturalized and non-US citizens, as CHIS did not collect additional information on immigration status beyond citizenship.

3.2 Definitions and Measures

Study Variables

Dependent and Independent Variable:

The dependent variable of the study was COVID-19 vaccination status. Vaccination status was determined by the question: (1) *Have you been fully vaccinated, partially vaccinated, or are you not vaccinated, for COVID-19*. The outcome was categorized as: not vaccinated, partially vaccinated, or fully vaccinated. Immigrant status, the primary independent variable, was categorized into: US-born citizen, naturalized citizen, and non-US citizen. The immigrant status was determined by the question: (1) *Are you a citizen of the United State.* We defined immigrant

status based on citizenship: naturalized citizens (foreign-born and obtained U.S. citizenship) or non-US citizens.

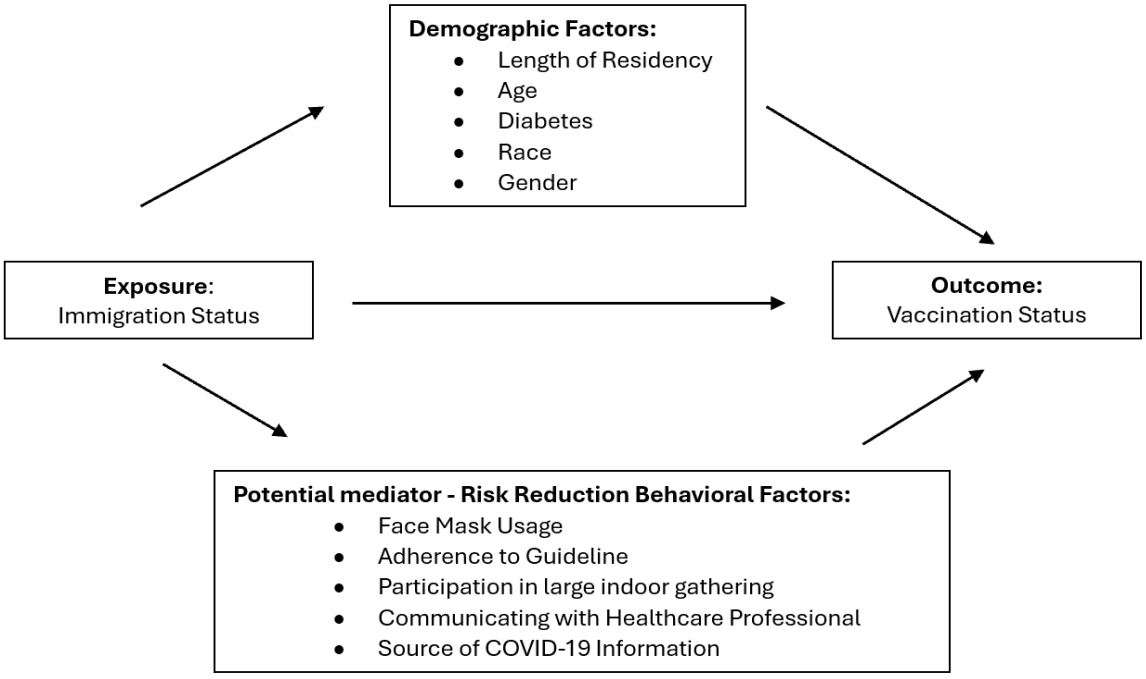
Co-Variates:

We assessed demographic and behavioral characteristics as covariates. Demographic factors included in this study were: length of residency (<5 years, 5-9 years, 10-14 years, ≥15 years),age (18-29, 30-39, 40-49, 50-59, 60-69, 70-70, ≥80), diabetic status (yes or no), sex (male or female), levels of English proficiency (fluent, very well, well, not well, not at all), and race (Hispanic, White, African American, Asian, American Indian/Alaskan Native, or two or more race).

Risk reduction behavioral factor were: contacted health professional about COVID-19 concerns (yes, or no), how often wore face cover in the past week (never, sometimes, usually, always, or did not leave home), how often followed state and local guidelines (never, sometimes, usually, or always), participated in indoor gatherings with over 1,000 attendees (yes or no), and most relied source of COVID-19 information (television, radio, newspaper, government, doctor, family members, friends, employer, social media, religious leader, community leader, or none of the above).

Figure 1 illustrated the relationships among exposure, covariates, and the outcome variable. This provided a graphical representation of how different factors influence COVID-19 vaccination status among the immigrant population.

FIGURE 1 Path diagram demonstration of direct and indirect impact on vaccination status



3.3 Statistical Analysis

Our study incorporated descriptive analysis, and polytomous (ordinal) logistic regression. Descriptive statistics provided an overview of the general characteristics of our study population. To ensure robustness, the datasets were adjusted using logistic regression. The adjustment was essential for incorporating covariates to the model to correct for potential biases.

The initial analysis with descriptive statistics outlined the characteristics of the variables. The analysis yielded numbers, percentages, and p-value for each variable. The Pearson Chi-square test was employed across each variable to assess their impact on vaccination status. The significance of each variable was determined through Pearson chi-squared test, with $p<0.05$ as significant. This dataset was organized by immigrant status to US-born, naturalized, and non-US citizen.

Polytomous (ordinal) logistic regression was conducted to adjust for covariates. Immigration status was set as the focal independent variable. The covariates were systematically grouped into demographic factors and risk reduction behavioral factors. Logistic regression model with demographic factor was labeled as Model 1, regression with behavioral factor as Model 2, and regression with both demographic and behavioral factor as Model 3. Unadjusted (crude) regression model was fitted with vaccination status and immigrant status. This unadjusted model provided a baseline for comparison with adjusted odds ratio obtained from the three additional models. Polytomous (ordinal) logistic regression analysis yielded adjusted odds ratio, 95% confidence intervals, and p-values.

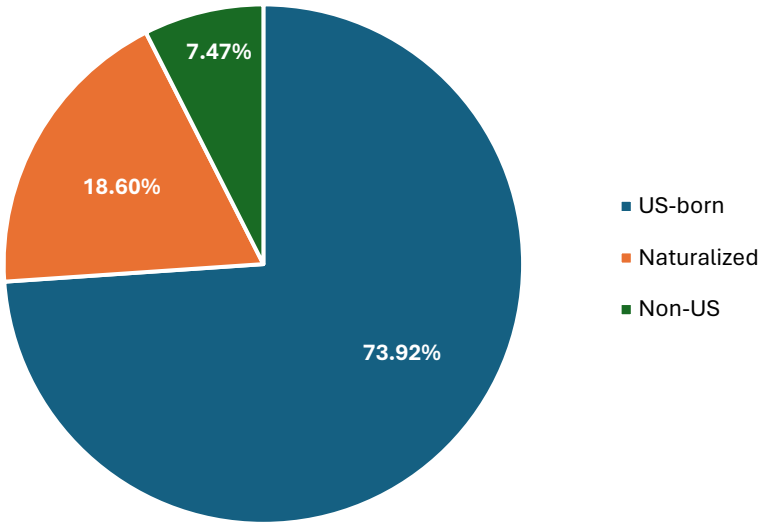
All analyses were performed using RStudio version 2023.12.1+402. This study was a secondary data analysis of deidentified, publicly available data. Due to the absence of interaction with or additional collection of identifiable information from human subjects, Institutional Review Board approval was not required.

Chapter 4: Results

4.1 Study Population and Characteristics

Our analysis of the 2022 CHIS dataset included 21,463 participants aged 18 years and older. Table 1 summarizes demographic and behavioral characteristics of the study sample by immigration status. A majority of the respondents were US-born citizens (73.92%), with naturalized citizens making up 18.6% and non-US citizens 7.47% of the sample (Fig. 2). Notably, a high full vaccination rate was observed across all groups, with 93.5% of naturalized, 88.7% of non-US, and 89.5% of US-born citizens reporting full vaccination, contributing to an overall full vaccination rate of 90.2%. US-born citizens had the highest prevalence of not being vaccinated (8.5%).

FIGURE 2: *Distribution of immigrant status among 2022 CHIS Study Population*



4.2 Demographics and Behaviors

Approximately 93% of naturalized citizens resided in the US for over 15 years compared to 55.95% of non-US citizens. White individuals represented the predominant racial group overall (48.6%), while Asians (44.5%) and Hispanics (50.7%) were the majorities among naturalized and non-US citizens, respectively. Compared to naturalized and non-US citizens, those who were US born were more likely to be female. The largest age group represented was those aged 60-69 years (22.3%), with the least participation from individuals aged 80 years and older (5.7%) overall. Compared to US born and naturalized citizens, non-US citizens were likely to be younger.

English proficiency varied by immigration status with the majority of naturalized citizens reporting that they spoke English “very well” (36%), and non-US citizens predominantly reporting that they spoke English “well” (30.8%). Health behaviors also varied by immigration status. Naturalized and non-US citizens tended to always wear face coverings when in public

(47.7% and 47.1%, respectively) compared to US-born citizens, who more commonly reported wearing them sometimes (29.8%). Television was the most replied upon source of COVID-19 information for all groups (34.9%). Among US-born citizens, newspapers were the second most relied upon source (14.0%). In contrast, naturalized and non-US citizens reported social media as their next predominant sources of information, 15.1% and 13.8% respectively. All variables were statistically significantly different between the groups (p <0.001) except contacting a health professional with COVID-19 concern (p=0.50).

Table 1: *Descriptive Statistics of sample population of adults aged >= 18 years (N = 21463) in the 2022 California Health Interview Survey by immigration status*[a]

	US-Born (N=15866)	Naturalized (N=3993)	Non-US (N=1604)	Overall (N=21463)	P-value[b]
VACCINATION STATUS					
Not Vaccinated	1345 (8.5%)	179 (4.5%)	102 (6.4%)	1626 (7.6%)	<0.001
Partially Vaccinated	321 (2.0%)	81 (2.0%)	80 (5.0%)	482 (2.2%)	
Fully Vaccinated	14200 (89.5%)	3733 (93.5%)	1422 (88.7%)	19355 (90.2%)	
LENGTH OF RESIDENCY					
15+ Years	15866 (100%)	3701 (92.7%)	896 (55.9%)	20463 (95.3%)	<0.001
10-14 Years	0 (0%)	174 (4.4%)	183 (11.4%)	357 (1.7%)	
5-9 Years	0 (0%)	99 (2.5%)	295 (18.4%)	394 (1.8%)	
<5 Years	0 (0%)	19 (0.5%)	230 (14.3%)	249 (1.2%)	
SEX					
Male	6615 (41.7%)	1890 (47.3%)	720 (44.9%)	9225 (43.0%)	<0.001
Female	9251 (58.3%)	2103 (52.7%)	884 (55.1%)	12238 (57.0%)	
AGE					
18-29	1582 (10.0%)	118 (3.0%)	182 (11.3%)	1882 (8.8%)	<0.001
30-39	2072 (13.1%)	368 (9.2%)	382 (23.8%)	2822 (13.1%)	
40-49	2141 (13.5%)	644 (16.1%)	433 (27.0%)	3218 (15.0%)	
50-59	2911 (18.3%)	1061 (26.6%)	344 (21.4%)	4316 (20.1%)	
60-69	3627 (22.9%)	980 (24.5%)	171 (10.7%)	4778 (22.3%)	
70-79	2542 (16.0%)	602 (15.1%)	71 (4.4%)	3215 (15.0%)	
80+	991 (6.2%)	220 (5.5%)	21 (1.3%)	1232 (5.7%)	
DIABETES					
No	14257 (89.9%)	3346 (83.8%)	1428 (89.0%)	19031 (88.7%)	<0.001
Yes	1609 (10.1%)	647 (16.2%)	176 (11.0%)	2432 (11.3%)	

Table 1: cont.

	US-Born (N=15866)	Naturalized (N=3993)	Non-US (N=1604)	Overall (N=21463)	P-value[b]
RACE					
White	9602 (60.5%)	650 (16.3%)	180 (11.2%)	10432 (48.6%)	<0.001
Hispanic	3478 (21.9%)	1428 (35.8%)	813 (50.7%)	5719 (26.6%)	
African American	979 (6.2%)	75 (1.9%)	18 (1.1%)	1072 (5.0%)	
American Indian	126 (0.8%)	2 (0.1%)	1 (0.1%)	129 (0.6%)	
Asian	874 (5.5%)	1776 (44.5%)	584 (36.4%)	3234 (15.1%)	
Two or More	807 (5.1%)	62 (1.6%)	8 (0.5%)	877 (4.1%)	
ENGLISH PROFICIENCY					
Fluent	13073 (82.4%)	923 (23.1%)	169 (10.5%)	14165 (66.0%)	<0.001
Very Well	2489 (15.7%)	1436 (36.0%)	420 (26.2%)	4345 (20.2%)	
Well	233 (1.5%)	1008 (25.2%)	493 (30.7%)	1734 (8.1%)	
Not Well	67 (0.4%)	532 (13.3%)	400 (24.9%)	999 (4.7%)	
Not At All	4 (0.0%)	94 (2.4%)	122 (7.6%)	220 (1.0%)	
HEALTH PROFESSIONAL CONSULT[cd]					
No	12729 (80.2%)	3236 (81.0%)	1286 (80.2%)	17251 (80.4%)	0.501
Yes	3137 (19.8%)	757 (19.0%)	318 (19.8%)	4212 (19.6%)	
FACE COVER USAGE[c]					
Never	3569 (22.5%)	407 (10.2%)	173 (10.8%)	4149 (19.3%)	<0.001
Sometimes	4735 (29.8%)	921 (23.1%)	342 (21.3%)	5998 (27.9%)	
Usually	3073 (19.4%)	729 (18.3%)	317 (19.8%)	4119 (19.2%)	
Always	4285 (27.0%)	1905 (47.7%)	755 (47.1%)	6945 (32.4%)	
Did not leave home	204 (1.3%)	31 (0.8%)	17 (1.1%)	252 (1.2%)	
PARTICIPATION IN INDOOR GATHERING (<1,000 ATTENDDES)[c]					
No	13725 (86.5%)	3646 (91.3%)	1486 (92.6%)	18857 (87.9%)	<0.001
Yes	2141 (13.5%)	347 (8.7%)	118 (7.4%)	2606 (12.1%)	
ADHERENCE TO STATE AND LOCAL GUIDELINE[c]					
Never	2048 (12.9%)	330 (8.3%)	152 (9.5%)	2530 (11.8%)	<0.001
Sometimes	2989 (18.8%)	617 (15.5%)	250 (15.6%)	3856 (18.0%)	
Usually	4457 (28.1%)	1024 (25.6%)	429 (26.7%)	5910 (27.5%)	
Always	6372 (40.2%)	2022 (50.6%)	773 (48.2%)	9167 (42.7%)	
MOST RELIED UPON SOURCE OF INFORMATION[d]					
None of These	977 (6.2%)	190 (4.8%)	64 (4.0%)	1231 (5.7%)	<0.001
TV	5326 (33.6%)	1603 (40.1%)	570 (35.5%)	7499 (34.9%)	
Radio	860 (5.4%)	204 (5.1%)	51 (3.2%)	1115 (5.2%)	
Newspaper	2217 (14.0%)	408 (10.2%)	117 (7.3%)	2742 (12.8%)	
Government	1986 (12.5%)	367 (9.2%)	110 (6.9%)	2463 (11.5%)	
Doctor	813 (5.1%)	155 (3.9%)	45 (2.8%)	1013 (4.7%)	
Family Members	603 (3.8%)	155 (3.9%)	51 (3.2%)	809 (3.8%)	

Friends	201 (1.3%)	56 (1.4%)	33 (2.1%)	290 (1.4%)
Employer	954 (6.0%)	241 (6.0%)	75 (4.7%)	1270 (5.9%)
Social Media	1881 (11.9%)	603 (15.1%)	475 (29.6%)	2959 (13.8%)
Religious Leader	23 (0.1%)	8 (0.2%)	7 (0.4%)	38 (0.2%)
Community Leaders	25 (0.2%)	3 (0.1%)	6 (0.4%)	34 (0.2%)

[a] Immigrant status categories include US-born (reference group), naturalized citizens, and non-US citizens
[b] P-values are derived from Pearson's Chi-Squared Test
[c] Data refers to behaviors reported in the past week
[d] Related solely to COVID-19

4.3 Threshold and Model Fit Statistics

The logistic regression analysis revealed two thresholds: the transition from 'Not Vaccinated' to 'Partially Vaccinated' categories was estimated at -2.4418 (SE = 0.0288, t = -84.9261), and from 'Partially Vaccinated' to 'Fully Vaccinated' at -2.1548 (SE = 0.0262, t = -82.3505) for the unadjusted model (Table 2). Upon adjustment for all variables, these thresholds changed significantly to -0.31 and -0.0001, respectively. The goodness-of-fit tests indicated that the unadjusted model had the least explanatory power (McFadden's R-squared = 0.004). In contrast, Model 3, incorporating both demographic and behavioral factors, had the highest explanatory power (McFadden's R-squared = 0.152).

Table 2: *Logistic Regression Threshold Estimate and Model Fit Statistics*

Model	Vaccination Status	Estimate	Std. Error	t-Value	McFadden's R-squared
Unadjusted[a]	Not Vaccinated to Partially Vaccinated	-2.4418	0.0288	-84.9261	0.004098
	Partially Vaccinated to Fully Vaccinated	-2.1548	0.0262	-82.3505	
Model 1[b]	Not Vaccinated to Partially Vaccinated	-2.1766	0.085	-25.617	0.083465
	Partially Vaccinated to Fully Vaccinated	-1.8864	0.0842	-22.4089	
Model 2[c]	Not Vaccinated to Partially Vaccinated	-0.3538	0.0782	-4.522	0.083812
	Partially Vaccinated to Fully Vaccinated	-0.0477	0.0779	-0.6121	
Model 3[d]	Not Vaccinated to Partially Vaccinated	-0.3111	0.1141	-2.7259	0.152035
	Partially Vaccinated to Fully Vaccinated	-0.0001	0.1139	-0.0007	

[a] Unadjusted model examines vaccination status transitions without additional adjustment
[b] Adjusted for demographic factors including length of residency, sex, age, diabetes status, and race.
[c] Adjusted for behavioral factors including health professional consultation, face cover usage, participation in large indoor gatherings, adherence to guidelines, and primary source of covid-19 information.
[d] Adjusted for both demographic and behavioral factors to provide a comprehensive model.

4.4 Logistic Regression

Figure 3 depicts the association of each variable with vaccination status after adjusting for both behavior and demographic factors. Table 3 details the crude and adjusted associations between various factors and COVID-19 vaccination. Naturalized citizens consistently had greater odds of vaccinated compared to US-born citizens across all models (unadjusted OR: 1.67; model 1 aOR: 1.41; model 2 aOR: 1.51; model3 aOR: 1.37), as further demonstrated in Figure 4 (see Appendix). Compared to US-born citizens, naturalized citizens had 37% increased odds of being vaccinated (aOR: 1.37; 95% CI: 1.15-1.64), while there were no significant differences between non-US citizens and US-born citizens (aOR: 1.03; CI: 0.81-1.31; p=0.83). A shorter length of residency in the US was associated with a higher likelihood of vaccination. Individuals residing for less than five years showed an 87% increase in likelihood of vaccination (aOR: 1.87; 95% CI: 1.09-3.19), and those with 5-9 years of residency had a 70% increased likelihood (aOR: 1.70; 95% CI: 1.09-2.66) compared to those with over 15 years of residency in the US.

Females were 19% less likely to be vaccinated compared to males (aOR: 0.81, 95% CI: 0.73 - 0.89). A progressive increase in age was associated with increase in the likelihood of vaccination. Individuals aged 60-69 years had 44% increased odds (aOR: 1.44, 95% CI: 1.18 - 1.74) and those 70-79 years had 79% increased odds (aOR: 1.79; 95% CI: 1.44 - 2.24) compared to the age group 18-29. Notably, individuals aged 80 years or older had exhibited double the likelihood of vaccination compared to aged 18-29 (aOR: 2.08, 95% CI: 1.54 - 2.82).

All racial group except Asians were less likely to be vaccinated compared to non-Hispanic Whites (Hispanic (aOR: 0.8; 95% CI: 0.7 - 0.92), African American (aOR: 0.54; 95% CI: 0.44 - 0.67), and American Indian (aOR: 0.26; 95% CI: 0.17 - 0.39)). Those identifying with two or more races had 36% decreased odds of vaccination (aOR: 0.64; 95% CI: 0.52 - 0.79)

compared to non-Hispanic Whites. In contrast, Asians had more than double the likelihood of vaccination (aOR: 2.07; 95% CI: 1.66 - 2.59) compared to White individuals. Those who did not speak English 'Well' or 'Not Well' had lower odds of being vaccinated (Well: aOR 0.69, 95% CI 0.55 - 0.87; Not Well: aOR 0.52, 95% CI: 0.39-0.67) compared to fluent English speakers. Those who reported not speaking English at all had 49% less likelihood of being vaccinated (aOR: 0.61; CI: 0.38-0.98) compared to fluent speakers.

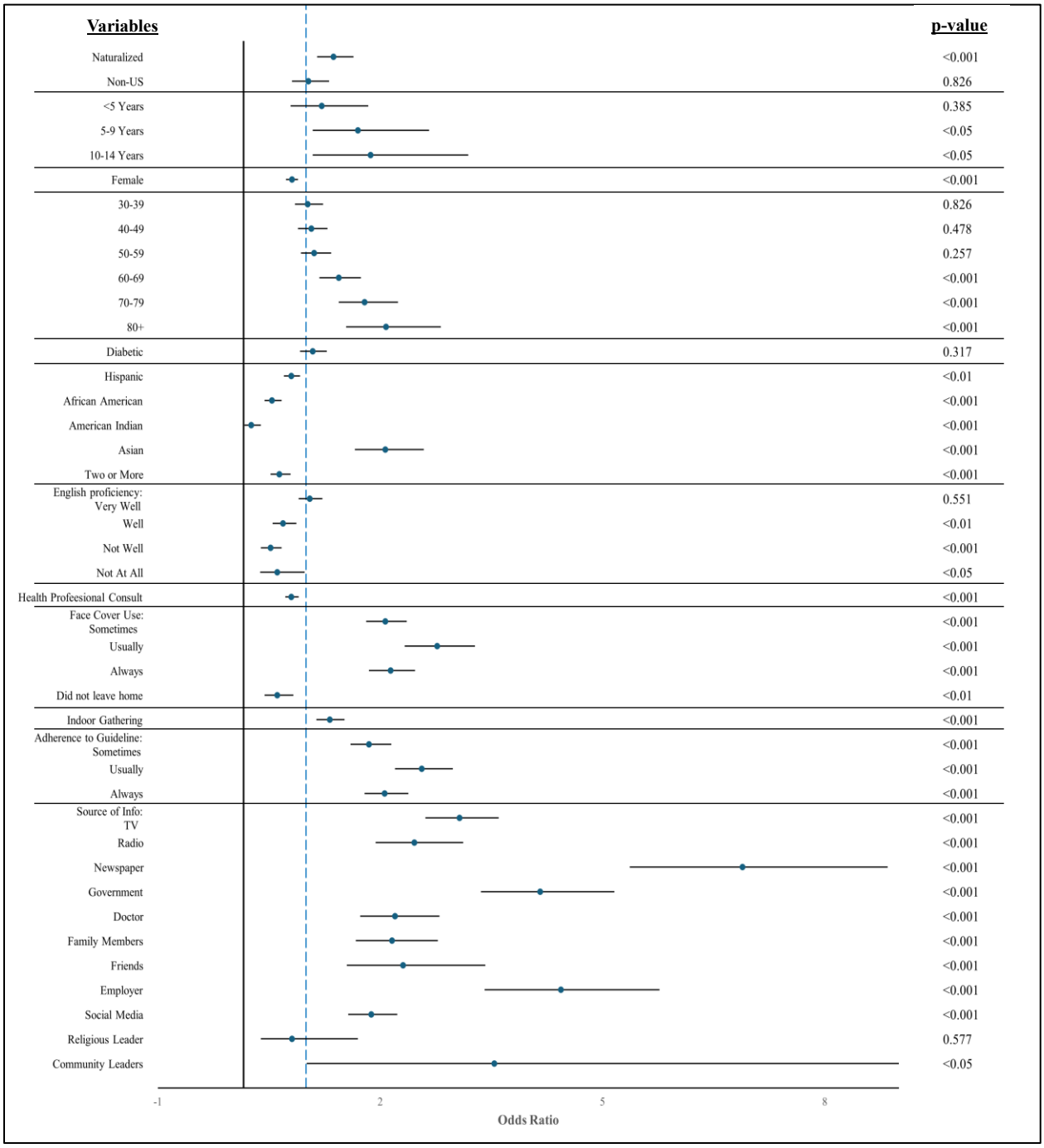
Individuals who consulted with a health professional regarding COVID-19 concerns were less likely to be vaccinated (aOR: 0.8; CI: 0.72-0.9) compared to those who did not consult a health professional. Regular face covering use revealed a higher odd of vaccination across all usage categories compared to those who never wore face coverings. Individuals who reported wearing face coverings 'sometimes' (aOR: 2.07; 95% CI: 1.81 - 2.36), 'usually' (aOR: 2.77; 95% CI: 2.33 - 3.28), or 'always' (aOR: 2.14; 95% CI: 1.85 - 2.47) had higher likelihood of vaccination compared to those who never wore face coverings. Those who did not leave their home had a reduced likelihood of being vaccinated (aOR: 0.61; 95% CI: 0.44 - 0.83) compared to those who never wore face coverings.

Participation at large indoor gatherings with over 1,000 attendees was 32% more likely amongst those who were vaccinated (aOR: 1.32; CI: 1.14-1.52) compared to those who were not. Compared to those who did not adhere to state and local guidelines, greater likelihood of vaccination was associated with those who sometimes (aOR: 1.85; 95% CI: 1.6 - 2.15), usually (aOR: 2.56; 95% CI: 2.2 - 2.98), or always (aOR: 2.06; 95% CI: 1.79 - 2.38) adhered to guidelines.

The source of information significantly impacted vaccination rate. Particularly, those who reported newspapers as their primary source of COVID-19 information had the highest

likelihood of vaccination (aOR: 6.89; 95% CI: 5.37 - 8.85) compared to those that did not report any source. Likelihood of vaccination was then followed by employer-provided information (aOR: 4.44; 95% CI: 3.41 - 5.77) and government sources (aOR: 4.16; 95% CI: 3.36 - 5.16). Other significant sources that positively affected vaccination likelihood include community leaders (aOR: 3.54; 95% CI: 1.01-12.44), television (aOR: 3.07; 95% CI: 2.61-3.6), radio (aOR: 2.46; 95% CI: 1.94-3.12), friends (aOR: 2.31; 95% CI: 1.55-3.42), doctor (aOR: 2.2; 95% CI: 1.73-2.8), family members (aOR: 2.16; 95% CI: 1.67-2.78), and social media (aOR: 1.88; 95% CI: 1.57-.2.23).

FIGURE 3: *Forest Plot Analysis for Model 3: Fully Adjusted Association between Demographic and Behavioral Factors with COVID-19 vaccination*



This figure illustrates the fully adjusted demographic and risk reduction behavioral factors with COVID-19 vaccination. The upper 95% confidence interval for the 'Community Leaders' category has been limited as it extends beyond the visible range of the plot due to space constraints and the possibility of its outlier status. All other variables are presented within the displayed range.

TABLE 3: *Comprehensive Polytomous Logistic Regression Analysis of Factors Influencing Covid-19 Vaccination*

	CRUDE			MODEL1 (demographic)[a]			MODEL 2 (behavioral)[b]			MODEL 3 (all)[c]		
VARIABLE	OR	95% CI	p-value	aOR	95% CI	p-value	aOR	95% CI	p-value	aOR	95% CI	p-value
CITIZENSHIP STATUS												
Us-Born Citizen	*ref*											
Naturalized	1.67	(1.48 - 1.95)	***	1.41	(1.19 - 1.67)	***	1.51	(1.31 - 1.74)	***	1.37	(1.15 - 1.64)	***
Non-Us Citizen	0.93	(0.80 - 1.11)	0.38	1.05	(0.83 - 1.33)	0.68	0.93	(0.78 - 1.1)	0.38	1.03	(0.81 - 1.31)	0.83
LENGTH OF RESIDENCY												
15+ Years	*ref*											
<5 Years				1.63	(0.97 - 2.73)	0.07				1.87	(1.09 - 3.19)	*
5-9 Years				1.52	(0.98 - 2.35)	0.06				1.7	(1.09 - 2.66)	*
10-14 Years				1.13	(0.74 - 1.7)	0.58				1.21	(0.79 - 1.84)	0.39
SEX												
Male	*ref*											
Female				0.93	(0.85 - 1.02)	0.13				0.81	(0.73 - 0.89)	***
AGE												
18-29	*ref*											
30-39				1.1	(0.92 - 1.31)	0.31				1.02	(0.85 - 1.23)	0.83
40-49				1.21	(1.01 - 1.44)	*				1.07	(0.89 - 1.29)	0.47
50-59				1.29	(1.09 - 1.54)	**				1.11	(0.93 - 1.34)	0.26
60-69				1.74	(1.46 - 2.08)	***				1.44	(1.18 - 1.74)	***
70-79				2.28	(1.86 - 2.8)	***				1.79	(1.44 - 2.24)	***
80+				2.62	(1.97 - 3.48)	***				2.08	(1.54 - 2.82)	***
DIABETES												
No	*ref*											
Yes				1.07	(0.92 - 1.25)	0.38				1.09	(0.92 - 1.28)	0.32
RACE												
White	*ref*											
Hispanic				0.79	(0.69 - 0.9)	***				0.8	(0.7 - 0.92)	**

TABLE 3: ***cont.***

	CRUDE			MODEL1 (demographic)[a]			MODEL 2 (behavioral)[b]			MODEL 3 (all)[c]		
VARIABLE	OR	95% CI	p-value	aOR	95% CI	p-value	aOR	95% CI	p-value	aOR	95% CI	p-value
African American				0.68	(0.56 - 0.83)	***				0.54	(0.44 - 0.67)	***
American Indian				0.25	(0.17 - 0.37)	***				0.26	(0.17 - 0.39)	***
Asian				2.5	(2.02 - 3.11)	***				2.07	(1.66 - 2.59)	***
Two Or More				0.62	(0.51 - 0.76)	***				0.64	(0.52 - 0.79)	***
ENGLISH PROFICIENCY												
Fluent	*ref*											
Very Well				1.16	(1 - 1.34)	*				1.05	(0.9 - 1.22)	0.55
Well				0.76	(0.61 - 0.95)	*				0.69	(0.55 - 0.87)	**
Not Well				0.57	(0.44 - 0.74)	***				0.52	(0.39 - 0.67)	***
Not At All				0.64	(0.41 - 1.02)	0.06				0.61	(0.38 - 0.98)	*
HEALTH PROFESSIONAL CONSULT[e]												
No	*ref*											
Yes							0.7	(0.63 - 0.78)	***	0.8	(0.72 - 0.9)	***
FACE COVER USAGE [d]												
Never	*ref*											
Sometimes							2.03	(1.79 - 2.32)	***	2.07	(1.81 - 2.36)	***
Usually							2.72	(2.3 - 3.22)	***	2.77	(2.33 - 3.28)	***
Always							1.92	(1.67 - 2.21)	***	2.14	(1.85 - 2.47)	***
Did Not Leave Home							0.63	(0.46 - 0.86)	**	0.61	(0.44 - 0.83)	**
PARTICIPATION IN INDOOR GATHERING (>1000 ATEENDEES)[d]												
No	*ref*											
Yes							1.26	(1.09 - 1.45)	**	1.32	(1.14 - 1.52)	***
ADHERENCE TO STATE & LOCAL GUIDELINED [d]												
Never	*ref*											
Sometimes							1.74	(1.51 - 2.02)	***	1.85	(1.6 - 2.15)	***
Usually							2.56	(2.2 - 2.98)	***	2.56	(2.2 - 2.98)	***

TABLE 3: *cont.*

	CRUDE			MODEL1 (demographic)[a]			MODEL 2 (behavioral)[b]			MODEL 3 (all)[c]		
VARIABLE	OR	95% CI	p-value	aOR	95% CI	p-value	aOR	95% CI	p-value	aOR	95% CI	p-value
Always							2.17	(1.88 - 2.5)	***	2.06	(1.79 - 2.38)	***
MOST RELIED UPON SOURCE OF INFORMATION[e]												
None Of These	*ref*											
Television							3.11	(2.66 - 3.64)	***	3.07	(2.61 - 3.6)	***
Radio							2.56	(2.02 - 3.23)	***	2.46	(1.94 - 3.12)	***
Newspaper							7.89	(6.16 - 10.11)	***	6.89	(5.37 - 8.85)	***
Government							4.05	(3.28 - 5.01)	***	4.16	(3.36 - 5.16)	***
Doctor							2.31	(1.83 - 2.93)	***	2.2	(1.73 - 2.8)	***
Family Members							2.08	(1.62 - 2.67)	***	2.16	(1.67 - 2.78)	***
Friends							2.41	(1.63 - 3.56)	***	2.31	(1.55 - 3.42)	***
Employer							4.09	(3.15 - 5.31)	***	4.44	(3.41 - 5.77)	***
Social Media							1.78	(1.5 - 2.11)	***	1.88	(1.57 - 2.23)	***
Religious Leader							0.72	(0.35 - 1.48)	0.37	0.81	(0.39 - 1.7)	0.577
Community Leaders							2.6	(0.77 - 8.76)	0.12	3.54	(1.01 - 12.44)	*

[a] adjusted for demographic factors including length of residency, sex, age, diabetes status, and race.
[b] adjusted for behavioral factors including health professional consultation, mask-wearing habits, participation in large indoor gatherings, adherence to guidelines, and primary source of covid-19 information.
[c] adjusted for both demographic and behavioral factors to provide a comprehensive model.
[d] indicates variables measured within the past week.
[e] related solely to covid-19
*p<0.05 **p<0.01 ***p<0.001 indicate levels of statistical significance, with more asterisks denoting higher levels of significance.

Chapter 5: Discussion

5.1 Preliminary Findings

The COVID-19 pandemic has highlighted pre-existing health disparities, particularly among immigrant populations, emphasizing the urgent need for comprehensive research. Despite the heightened awareness of these disparities, there remains a notable gap in understanding the impact of COVID-19 vaccination uptake among immigrants. Our study aimed to fill this gap by investigating the influence of immigration status on COVID-19 vaccination rates. By exploring factors beyond the traditionally studied variables, we aimed to gain a more nuanced understanding of vaccination behavior among immigrants.

Our analysis of vaccination thresholds revealed notable insight in the progression from partial to full vaccination status. Adjusting for behavioral factors attenuated the initial resistance, emphasizing the significant influence of behavior on vaccine uptake. These findings suggest that individuals engaging in protective behaviors are more likely to vaccinate. Moreover, the near-zero threshold observed after accounting for all factors indicates an environment favorable for full vaccination when considering the combination of behavior and demographics. The substantial increase in McFadden's R-squared value from 0.004 to 0.152 further supports the enhanced explanatory power of our fully adjusted model, reinforcing the robustness of our findings.

5.1.1 Immigrant Status and Vaccination

Vaccine uptake is intricate and multifaceted, influenced by a spectrum of factors. Our study revealed a higher likelihood of vaccination among naturalized citizens compared to US-born citizens. These findings are consistent with studies conducted in other regions, such as Qatar and China, which reported higher acceptance of COVID-19 vaccines among migrant

populations compared to native-born citizens (Alabdulla et al., 2021; Han et al., 2021; Khaled et al., 2021). However, these studies generally do not differentiate between naturalized and non-citizen immigrants, often comparing native-born citizens to all immigrants as a group.

Significantly, our research provides a more detailed perspective by distinguishing between naturalized and non-US citizens, allowing for a deeper understanding of vaccination behaviors within these groups. This distinction is critical as it reveals the variability within the immigrant population that often goes unnoticed when immigrants are categorized broadly. For instance, while naturalized citizens showed a significantly higher likelihood of vaccination, we discovered varying likelihood with no statistical significance between non-US citizens and US-born citizens.

The likelihood of vaccination for non-US citizens varied based on the model adjustments. The decrease in likelihood of vaccination with adjusting for behavioral factors suggests that barriers to engaging in protective behaviors, which are often similar to barriers to vaccination, significantly impact vaccine uptake within immigrant groups. This pattern is consistent with previous findings, indicating that foreign-born non-US citizens typically have lower vaccination rates compared to US-born individuals for various vaccine-preventable diseases (Daniels et al., 2022; Lu et al., 2014). Studies highlight that misinformation, access issues, cultural biases, and distrust of authorities, which can deter individuals from protective health behaviors, are likely influencing vaccination decisions among Refugee and Immigrant Minority (RIM) communities (Daniels et al., 2022; Knights et al., 2021). Additionally, fears of deportation, particularly among undocumented immigrants, have been shown to exacerbate vaccine hesitancy, further illustrating how barriers to protective behaviors overlap with barriers to vaccination uptake (Abba-Aji et al., 2022; Dawson et al., 2020).

Although there is substantial research indicating lower vaccination likelihood among immigrants, the apparent lack of significance between non-US citizens and US-born citizens in our study might obscure underlying disparities among subgroups of non-US citizens, a factor often overlooked in aggregate data analysis.

We initially expected that an increase in length of residency would correlate with higher vaccination rate. In theory, longer duration of residence is accompanied with higher degree of acculturation (Berry, 1992). This is typically translated to a higher degree of health care utilization (Bermúdez-Parsai et al., 2012; Echeverria & Carrasquillo, 2006; Yong et al., 2016). However, our study revealed a decrease in vaccination likelihood with an increase in length of residency. This finding also contradicts previous research on influenza vaccine that revealed longer residency correlating with higher vaccination rates among immigrants with longer residency compared to recent immigrants (Fabiani et al., 2017). This may be attributed to the greater proportion of US-born citizens in our dataset who, exhibited longer length of residency and lower vaccination rates.

Our study reveals a higher prevalence of US-born citizens falling into the not-vaccinated category for COVID-19, despite historical trends showing higher vaccination rates among US citizens for other vaccine-preventable diseases (Daniels et al., 2022; Lu et al., 2014). This discrepancy may stem from unique aspects of the COVID-19 pandemic, such as heightened vaccine hesitancy and widespread conspiracy beliefs within certain segments of the US population. Although specific research on the reduced vaccination likelihood among US-born citizens for COVID-19 is limited, existing studies suggest that political ideologies and conspiracy beliefs are significant contributors to vaccine hesitancy. Political ideologies and conspiracy beliefs, particularly those related to COVID-19, have been strongly linked to vaccine

refusal, with higher levels of conspiracy beliefs correlating with a decreased likelihood of accepting the COVID-19 vaccination (Kowalska-Duplaga & Duplaga, 2023; Pertwee et al., 2022). Additionally, public skepticism about the severity of COVID-19 and its origins, especially prevalent among conservative groups, may further drive vaccine hesitancy in the US (Schaeffer, 2020; Tanase et al., 2022).

5.1.2 Influence of behavior and demographic factors

Our study revealed the multifaceted dynamics influencing vaccination behavior among immigrant populations. The crucial role of English proficiency in vaccination likelihood among immigrants was highlighted in our results. Immigrants with limited English proficiency exhibited significantly lower vaccination rates, underscoring the importance of language-accessible healthcare services in promoting vaccine uptake. Our study revealed that decrease in English proficiency was correlated with a decrease in vaccination. This aligns with previous research highlighting language barriers as a significant obstacle to healthcare access and influenza vaccine coverage among immigrants (Karki et al., 2016; Lu et al., 2014).

Association of age with vaccination rate were evident with older individuals demonstrating higher vaccination likelihood, in line with existing research (Latkin et al., 2021; Lazarus et al., 2021; Ogilvie et al., 2021; Robinson et al., 2021). Our study also uncovered an intriguing finding regarding the significant association between relying on newspapers as the primary source of COVID-19 information and a significantly higher likelihood of vaccination. Despite the relatively low utilization of newspapers as a source of information, this finding prompts further examination. One plausible explanation could be attributed to age demographics. Older individuals, who are more likely to be vaccinated, tend to consume newspapers more frequently (Thurman, 2018). Given this correlation between age and newspaper readership, the

observed link between newspaper reliance and vaccination likelihood becomes more comprehensible.

Additionally, our study identified several risk reduction behaviors associated with increased vaccination likelihood, such as wearing face coverings, which may be influenced by the perceived effectiveness of mask use in preventing COVID-19 transmission. Our results support previous research indicating that those with negative vaccination intentions were less likely to engage in prevention behaviors (Lam et al., 2022; Latkin et al., 2021). However, unexpected findings emerged regarding consultation with health professionals, where individuals who sought advice regarding COVID-19 concerns exhibited lower vaccination likelihood. This unexpected association may stem from various factors, including a sense of confidence or satisfaction with prior vaccination decisions among those who had already been vaccinated, contrasting with a lack of concern or indifference towards seeking medical advice among those who abstained from consultation.

5.2 Strengths and Limitations:

Our study makes a significant contribution to understanding COVID-19 vaccination behavior among immigrant populations in the United States. By distinguishing between naturalized and non-US citizens, we provide valuable insight into subgroups of immigrants and their health. Leveraging the robust 2022 CHIS dataset, our analysis benefits from a large sample size, enhancing the reliability and generalizability of our findings. Moreover, our multifaceted approach, encompassing both demographic and behavioral factors, sheds light on the complex dynamics influencing vaccine decision-making among immigrants. By separating the broad category of "immigrant," we uncover unique insights into the barriers and facilitators of COVID-

19 vaccine uptake among various subgroups, which is crucial for promoting health equity and guiding targeted interventions.

While our study sheds light on vaccination behaviors among immigrant populations, it is essential to acknowledge several limitations. These include data ambiguity, disproportionate representation, and the cross-sectional nature of the analysis. The ambiguity surrounding which immigrant populations were classified as non-US citizens may have resulted in an underrepresentation of certain immigrant groups, hindering a comprehensive understanding of immigrant vaccine behaviors. Additionally, the disproportionate representation between naturalized citizens and non-US citizens in our dataset may have skewed our results and limited generalizability. The lack of statistical significance for certain demographic and behavioral factors related to vaccination rates highlights the need for larger, more representative datasets.

The cross-sectional nature of our study also limits our ability to capture the dynamic nature of the pandemic and its impact on vaccine behaviors over time. In addition, the implementation of vaccine mandates during the COVID-19 pandemic poses challenges in interpreting vaccine behaviors accurately. The high vaccination rates observed in our dataset may be attributed to mandates rather than individual choices. Thus, considering booster vaccination records could offer a more comprehensive understanding of vaccine decisions, especially given that boosters were not mandated during the study period.

5.3 Conclusion

Our study provides comprehensive insight into the dynamics of COVID-19 vaccination behaviors among immigrant populations in the United States. Leveraging the 2022 CHIS dataset, we identified significant patterns and determinants influencing vaccination among different

immigrant groups. Notably, naturalized citizens consistently exhibited a higher vaccination likelihood compared to US-born citizens.

The results of our study underscore the need for more nuanced public health strategies and research approaches that recognize and address the diverse immigrant populations. Understanding specific barriers and facilitators to vaccine uptake is crucial for developing equitable health strategies tailored to the unique needs of various immigrant subgroups. Such targeted efforts ensure that no community is left behind in public health efforts. It is essential for healthcare practitioners and policymakers to engage in ongoing research that differentiates immigrant subgroups to truly understand and address their distinct healthcare needs. This targeted approach is fundamental to diminishing health disparities and enhancing health outcomes across immigrant communities, ultimately contributing to the broader goal of improving health equity.

Thus, future research should address the limitations of this study by collecting longitudinal data and delving deeper into the different immigrant subgroups to capture a true representation of vaccine-related decision-making of immigrants. Addressing these limitations and conducting further research on COVID-19 booster vaccination rates among immigrant populations will be crucial in providing deeper insights to this community.

Chapter 6: References

Abba-Aji, M., Stuckler, D., Galea, S., & McKee, M. (2022). Ethnic/racial minorities' and migrants' access to COVID-19 vaccines: A systematic review of barriers and facilitators. *Journal of Migration and Health*, *5*, 100086. https://doi.org/10.1016/j.jmh.2022.100086

Abdi, I., Gidding, H., Leong, R. N., Moore, H. C., Seale, H., & Menzies, R. (2021). Vaccine coverage in children born to migrant mothers in Australia: A population-based cohort study. *Vaccine*, *39*(6), 984–993. https://doi.org/10.1016/j.vaccine.2020.12.058

Alabdulla, M., Reagu, S. M., Al-Khal, A., Elzain, M., & Jones, R. M. (2021). COVID-19 vaccine hesitancy and attitudes in Qatar: A national cross-sectional survey of a migrant-majority population. *Influenza and Other Respiratory Viruses*, *15*(3), 361–370.

Anderson, B., & Blinder, S. (2024). Who Counts as a Migrant? Definitions and their Consequences. *The Migration Observatory*. https://migrationobservatory.ox.ac.uk/resources/briefings/who-counts-as-a-migrant-definitions-and-their-consequences/

Batalova, J. (2024). Frequently Requested Statistics on Immigrants and Immigration in the United States. *Migration Policy Institute*. https://www.migrationpolicy.org/article/frequently-requested-statistics-immigrants-and-immigration-united-states

Bermúdez-Parsai, M., Mullins Geiger, J. L., Marsiglia, F. F., & Coonrod, D. V. (2012). Acculturation and Health Care Utilization among Mexican Heritage Women in the United States. *Maternal and Child Health Journal*, *16*(6), 1173–1179. https://doi.org/10.1007/s10995-011-0841-6

Berry, J. W. (1992). Acculturation and Adaptation in a New Society. *International Migration*, *30*(s1), 69–85. https://doi.org/10.1111/j.1468-2435.1992.tb00776.x

Biswas, M., Rahaman, S., Biswas, T. K., Haque, Z., & Ibrahim, B. (2020). Association of Sex, Age, and Comorbidities with Mortality in COVID-19 Patients: A Systematic Review and Meta-Analysis. *Intervirology*, *64*(1), 36–47. https://doi.org/10.1159/000512592

Camarota, S. A., & Zeigler, K. (2023). *In October 2023, the Foreign-Born Share Was the Highest in History*. https://cis.org/Report/October-2023-ForeignBorn-Share-Was-Highest-History

CDC. (2021, November 16). *HPV Vaccine Safety and Effectiveness*. https://www.cdc.gov/vaccines/vpd/hpv/hcp/safety-effectiveness.html

CDC. (2022, September 22). *Adult vaccination—Reasons to vaccinate.* Centers for Disease Control and Prevention. https://www.cdc.gov/vaccines/adults/reasons-to-vaccinate.html

CDC. (2023a, February 8). *Influenza (Flu)*. https://www.cdc.gov/flu/vaccines-work/vaccineeffect.htm

CDC. (2023b, May 11). *COVID-19 Medical Conditions*. Centers for Disease Control and Prevention. https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/people-with-medical-conditions.html

Chirico, F., Teixeira da Silva, J. A., Tsigaris, P., & Sharun, K. (2022). Safety & effectiveness of COVID-19 vaccines: A narrative review. *The Indian Journal of Medical Research*, *155*(1), 91–104. https://doi.org/10.4103/ijmr.IJMR_474_21

Commodore-Mensah, Y., Ukonu, N., Obisesan, O., Aboagye, J. K., Agyemang, C., Reilly, C. M., Dunbar, S. B., & Okosun, I. S. (2016). Length of Residence in the United States is Associated With a Higher Prevalence of Cardiometabolic Risk Factors in Immigrants: A

Contemporary Analysis of the National Health Interview Survey. *Journal of the American Heart Association*, *5*(11). https://doi.org/10.1161/JAHA.116.004059

Daniels, D., Imdad, A., Buscemi-Kimmins, T., Vitale, D., Rani, U., Darabaner, E., Shaw, A., & Shaw, J. (2022). Vaccine hesitancy in the refugee, immigrant, and migrant population in the United States: A systematic review and meta-analysis. *Human Vaccines & Immunotherapeutics*, *18*(6), 2131168. https://doi.org/10.1080/21645515.2022.2131168

Dawson, M. A., Giger, J. N., Powell-Young, Y., & Brannon, C. B. (2020). Why African-Americans are hesitant to take the newly proposed COVID-19 vaccines: Tuskegee revisited. *J Natl Black Nurses Assoc*, vi–viii.

Demeke, J., McFadden, S. M., Dada, D., Djiometio, J. N., Vlahov, D., Wilton, L., Wang, M., & Nelson, L. E. (2022). Strategies that Promote Equity in COVID-19 Vaccine Uptake for Undocumented Immigrants: A Review. *Journal of Community Health*, *47*(3), 554–562. https://doi.org/10.1007/s10900-022-01063-x

Douglas, P., Cetron, M., & Spiegel, P. (2019). Definitions matter: Migrants, immigrants, asylum seekers and refugees. *Journal of Travel Medicine*, *26*(2), taz005. https://doi.org/10.1093/jtm/taz005

Echeverria, S. E., & Carrasquillo, O. (2006). The Roles of Citizenship Status, Acculturation, and Health Insurance in Breast and Cervical Cancer Screening Among Immigrant Women. *Medical Care*, *44*(8), 788–792. https://doi.org/10.1097/01.mlr.0000215863.24214.41

Ehreth, J. (2003). The value of vaccination: A global perspective. *Vaccine*, *21*(27), 4105–4117. https://doi.org/10.1016/S0264-410X(03)00377-3

Esterline, C., & Batalova, J. (2022). Frequently Requested Statistics on Immigrants and Immigration in the United States. *Migration Policy Institute*.

https://www.migrationpolicy.org/article/frequently-requested-statistics-immigrants-and-immigration-united-states-2022

Fabiani, M., Di Napoli, A., Riccardo, F., Gargiulo, L., Declich, S., & Petrelli, A. (2017). [Differences in influenza vaccination coverage among subgroups of adult immigrants residing in Italy at risk for complications (2012-2013)]. *Epidemiologia & Prevenzione*, *41*(3-4S1), 50–56. https://doi.org/10.19191/EP17.3-4S1.P050.065

Fabiani, M., Riccardo, F., Di Napoli, A., Gargiulo, L., Declich, S., & Petrelli, A. (2016). Differences in Influenza Vaccination Coverage between Adult Immigrants and Italian Citizens at Risk for Influenza-Related Complications: A Cross-Sectional Study. *PLOS ONE*, *11*(11), e0166517. https://doi.org/10.1371/journal.pone.0166517

Gimeno-Feliu, L. A., Calderón-Larrañaga, A., Díaz, E., Laguna-Berna, C., Poblador-Plou, B., Coscollar-Santaliestra, C., & Prados-Torres, A. (2019). The definition of immigrant status matters: Impact of nationality, country of origin, and length of stay in host country on mortality estimates. *BMC Public Health*, *19*(1), 247. https://doi.org/10.1186/s12889-019-6555-1

Guttmann, A., Gandhi, S., Wanigaratne, S., Lu, H., Ferreira-Legere, L. E., Paul, J., Gozdyra, P., Campbell, T., & Chung, H. (2020). *COVID-19 in Immigrants, Refugees and Other Newcomers in Ontario: Characteristics of Those Tested and Those Confirmed Positive, as of June 13, 2020*. https://www.ices.on.ca/publications/research-reports/covid-19-in-immigrants-refugees-and-other-newcomers-in-ontario-characteristics-of-those-tested-and-those-confirmed-positive-as-of-june-13-2020/

Han, K., Francis, M. R., Zhang, R., Wang, Q., Xia, A., Lu, L., Yang, B., & Hou, Z. (2021). Confidence, acceptance and willingness to pay for the COVID-19 vaccine among migrants in Shanghai, China: A cross-sectional study. *Vaccines*, *9*(5), 443.

Hayward, S. E., Deal, A., Cheng, C., Crawshaw, A., Orcutt, M., Vandrevala, T. F., Norredam, M., Carballo, M., Ciftci, Y., Requena-Méndez, A., Greenaway, C., Carter, J., Knights, F., Mehrotra, A., Seedat, F., Bozorgmehr, K., Veizis, A., Campos-Matos, I., Wurie, F., … Hargreaves, S. (2021). Clinical outcomes and risk factors for COVID-19 among migrant populations in high-income countries: A systematic review. *Journal of Migration and Health*, *3*, 100041. https://doi.org/10.1016/j.jmh.2021.100041

Hill, J., Rodriguez, D. X., & McDaniel, P. N. (2021). Immigration status as a health care barrier in the USA during COVID-19. *Journal of Migration and Health*, *4*, 100036. https://doi.org/10.1016/j.jmh.2021.100036

Holder, J. (2021, January 29). Tracking Coronavirus Vaccinations Around the World. *The New York Times*. https://www.nytimes.com/interactive/2021/world/covid-vaccinations-tracker.html

International Organization for Migration. (2019). Glossary on Migration. *International Organization for Migration*.

International Organization for Migration. (2023, July 11). *Migration data relevant for the COVID-19 pandemic*. Migration Data Portal. https://www.migrationdataportal.org/themes/migration-data-relevant-covid-19-pandemic

Jang, S. H., & Kang, J. (2021). Factors Associated with Influenza Vaccination Uptake among U.S. Adults: Focus on Nativity and Race/Ethnicity. *International Journal of*

Environmental Research and Public Health, *18*(10), 5349. https://doi.org/10.3390/ijerph18105349

Kandula, N. R., Diez-Roux, A. V., Chan, C., Daviglus, M. L., Jackson, S. A., Ni, H., & Schreiner, P. J. (2008). Association of Acculturation Levels and Prevalence of Diabetes in the Multi-Ethnic Study of Atherosclerosis (MESA). *Diabetes Care*, *31*(8), 1621–1628. https://doi.org/10.2337/dc07-2182

Karki, S., Dyda, A., Newall, A., Heywood, A., MacIntyre, C. R., McIntyre, P., Banks, E., & Liu, B. (2016). Comparison of influenza vaccination coverage between immigrant and Australian-born adults. *Vaccine*, *34*(50), 6388–6395. https://doi.org/10.1016/j.vaccine.2016.10.012

KFF. (2023, September 17). Key Facts on Health Coverage of Immigrants. *KFF*. https://www.kff.org/racial-equity-and-health-policy/fact-sheet/key-facts-on-health-coverage-of-immigrants/

Khaled, S. M., Petcu, C., Bader, L., Amro, I., Al-Hamadi, A. M. H., Al Assi, M., Ali, A. A. M., Le Trung, K., Diop, A., & Bellaj, T. (2021). Prevalence and potential determinants of COVID-19 vaccine hesitancy and resistance in Qatar: Results from a nationally representative survey of Qatari nationals and migrants between December 2020 and January 2021. *Vaccines*, *9*(5), 471.

Kim, H. N., Lan, K. F., Nkyekyer, E., Neme, S., Pierre-Louis, M., Chew, L., & Duber, H. C. (2020). Assessment of Disparities in COVID-19 Testing and Infection Across Language Groups in Seattle, Washington. *JAMA Network Open*, *3*(9), e2021213. https://doi.org/10.1001/jamanetworkopen.2020.21213

Knights, F., Carter, J., Deal, A., Crawshaw, A. F., Hayward, S. E., Jones, L., & Hargreaves, S. (2021). Impact of COVID-19 on migrants' access to primary care and implications for vaccine roll-out: A national qualitative study. *British Journal of General Practice*, *71*(709), e583–e595.

Kolker, A., & Heisler, E. (2022). *Immigrants' Access to Health Care* (R47351). U.S. Congressional Research Service.

Kowalska-Duplaga, K., & Duplaga, M. (2023). The association of conspiracy beliefs and the uptake of COVID-19 vaccination: A cross-sectional study. *BMC Public Health*, *23*(1), 672. https://doi.org/10.1186/s12889-023-15603-0

Lam, C. N., Kaplan, C., & Saluja, S. (2022). Relationship between mask wearing, testing, and vaccine willingness among Los Angeles County adults during the peak of the COVID-19 pandemic. *Translational Behavioral Medicine*, *12*(3), 480–485. https://doi.org/10.1093/tbm/ibab150

Larsson, E. C., Wittberg, E., & Lundåsen, S. W. (2022). Variations in vaccination uptake: COVID-19 vaccination rates in Swedish municipalities. *PLOS Global Public Health*, *2*(10), e0001204. https://doi.org/10.1371/journal.pgph.0001204

Latkin, C. A., Dayton, L., Yi, G., Colon, B., & Kong, X. (2021). Mask usage, social distancing, racial, and gender correlates of COVID-19 vaccine intentions among adults in the US. *PLOS ONE*, *16*(2), e0246970. https://doi.org/10.1371/journal.pone.0246970

Lazarus, J. V., Ratzan, S. C., Palayew, A., Gostin, L. O., Larson, H. J., Rabin, K., Kimball, S., & El-Mohandes, A. (2021). A global survey of potential acceptance of a COVID-19 vaccine. *Nature Medicine*, *27*(2), 225–228. https://doi.org/10.1038/s41591-020-1124-9

Lin, C. J., Nowalk, M. P., Toback, S. L., Rousculp, M. D., Raymund, M., Ambrose, C. S., & Zimmerman, R. K. (2010). Importance of vaccination habit and vaccine choice on influenza vaccination among healthy working adults. *Vaccine*, *28*(48), 7706–7712. https://doi.org/10.1016/j.vaccine.2010.07.009

Lin, S. (2022). COVID-19 Pandemic and Im/migrants' Elevated Health Concerns in Canada: Vaccine Hesitancy, Anticipated Stigma, and Risk Perception of Accessing Care. *Journal of Immigrant and Minority Health*, *24*(4), 896–908. https://doi.org/10.1007/s10903-022-01337-5

Loue, S., & Bunce, A. (1999). *The Assessment of Immigration Status in Health Research*. National Center for Health Statistics.

Lu, P., Rodriguez-Lainz, A., O'Halloran, A., Greby, S., & Williams, W. W. (2014). Adult Vaccination Disparities Among Foreign-Born Populations in the U.S., 2012. *American Journal of Preventive Medicine*, *47*(6), 722–733. https://doi.org/10.1016/j.amepre.2014.08.009

MacDonald, S. E., Paudel, Y. R., & Du, C. (2022). *COVID-19 vaccine coverage among immigrants and refugees in Alberta: A population-based cross-sectional study* (p. 2022.04.11.22273644). medRxiv. https://doi.org/10.1101/2022.04.11.22273644

Mapouka, M., Idris, M. S. M., Adejumo, F. F., Carlough, M. C., & Morillo, J. (2022). *Determinants of Complete COVID-19 Vaccination Status Among Immigrant Population in North Carolina USA, Qualtrics Survey July-August 202*. https://doi.org/10.2139/ssrn.4285907

Matlin, S. A., Smith, A. C., Merone, J., LeVoy, M., Shah, J., Vanbiervliet, F., Vandentorren, S., Vearey, J., & Saso, L. (2022). The Challenge of Reaching Undocumented Migrants with

COVID-19 Vaccination. *International Journal of Environmental Research and Public Health*, *19*(16), 9973. https://doi.org/10.3390/ijerph19169973

Mikolajczyk, R. T., Akmatov, M. K., Stich, H., Krämer, A., & Kretzschmar, M. (2008). Association between acculturation and childhood vaccination coverage in migrant populations: A population based study from a rural region in Bavaria, Germany. *International Journal of Public Health*, *53*(4), 180–187. https://doi.org/10.1007/s00038-008-8002-4

Moghadas, S. M., Vilches, T. N., Zhang, K., Wells, C. R., Shoukat, A., Singer, B. H., Meyers, L. A., Neuzil, K. M., Langley, J. M., Fitzpatrick, M. C., & Galvani, A. P. (2021). The impact of vaccination on COVID-19 outbreaks in the United States. *medRxiv*, 2020.11.27.20240051. https://doi.org/10.1101/2020.11.27.20240051

National Academies of Sciences, E., and Medicine. (2018). *Immigration as a Social Determinant of Health: Proceedings of a Workshop*. The National Academies Press. https://doi.org/10.17226/25204

NHS. (2023, March 28). *Why vaccination is important and the safest way to protect yourself*. Nhs.Uk. https://www.nhs.uk/vaccinations/why-vaccination-is-important-and-the-safest-way-to-protect-yourself/

OECD. (2022). What has been the impact of the COVID-19 pandemic on immigrants? An update on recent evidence. *OECD*. https://www.oecd.org/coronavirus/policy-responses/what-has-been-the-impact-of-the-covid-19-pandemic-on-immigrants-an-update-on-recent-evidence-65cfc31c/

Ogilvie, G. S., Gordon, S., Smith, L. W., Albert, A., Racey, C. S., Booth, A., Gottschlich, A., Goldfarb, D., Murray, M. C. M., Galea, L. A. M., Kaida, A., Brotto, L. A., &

Sadarangani, M. (2021). Intention to receive a COVID-19 vaccine: Results from a population-based survey in Canada. *BMC Public Health*, *21*(1), 1017. https://doi.org/10.1186/s12889-021-11098-9

Page, K. R., Genovese, E., Franchi, M., Cella, S., Fiorini, G., Tlili, R., Salazar, S., Duvoisin, A., Cailhol, J., & Jackson, Y. (2022). COVID-19 vaccine hesitancy among undocumented migrants during the early phase of the vaccination campaign: A multicentric cross-sectional study. *BMJ Open*, *12*(3), e056591. https://doi.org/10.1136/bmjopen-2021-056591

Pal, R., Bhadada, S. K., & Misra, A. (2021). COVID-19 vaccination in patients with diabetes mellitus: Current concepts, uncertainties and challenges. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *15*(2), 505–508. https://doi.org/10.1016/j.dsx.2021.02.026

Pedraza, L., Villela, R., Kamatgi, V., Cocuzzo, K., Correa, R., & Lisigurski, M. Z. (2022). The Impact of COVID-19 in the Latinx Community. *HCA Healthcare Journal of Medicine*, *3*(3), 97–104. https://doi.org/10.36518/2689-0216.1387

Perruchoud, R., & Redpath-Cross, J. (2011). *Glossary on Migration (2nd Edition)*. International Organization for Migration.

Pertwee, E., Simas, C., & Larson, H. J. (2022). An epidemic of uncertainty: Rumors, conspiracy theories and vaccine hesitancy. *Nature Medicine*, *28*(3), 456–459. https://doi.org/10.1038/s41591-022-01728-z

Pottie, K., Greenaway, C., Feightner, J., Welch, V., Swinkels, H., Rashid, M., Narasiah, L., Kirmayer, L. J., Ueffing, E., MacDonald, N. E., Hassan, G., McNally, M., Khan, K., Buhrmann, R., Dunn, S., Dominic, A., McCarthy, A. E., Gagnon, A. J., Rousseau, C., …

Health, coauthors of the C. C. for I. and R. (2011). Evidence-based clinical guidelines for immigrants and refugees. *CMAJ*, *183*(12), E824–E925. https://doi.org/10.1503/cmaj.090313

Rafiqul, A., Hossen, M. S., & Huda, S. (2021). COVID-19 Vaccination and Undocumented Migrants. *Asia Pacific Journal of Public Health*, *34*, 101053952110531. https://doi.org/10.1177/10105395211053162

Robinson, E., Jones, A., Lesser, I., & Daly, M. (2021). International estimates of intended uptake and refusal of COVID-19 vaccines: A rapid systematic review and meta-analysis of large nationally representative samples. *Vaccine*, *39*(15), 2024–2034. https://doi.org/10.1016/j.vaccine.2021.02.005

Rojas-Venegas, M., Cano-Ibáñez, N., & Khan, K. S. (2022). Vaccination coverage among migrants: A systematic review and meta-analysis. *Medicina de Familia. SEMERGEN*, *48*(2), 96–105. https://doi.org/10.1016/j.semerg.2021.10.008

Sallam, M. (2021). COVID-19 Vaccine Hesitancy Worldwide: A Concise Systematic Review of Vaccine Acceptance Rates. *Vaccines*, *9*(2), Article 2. https://doi.org/10.3390/vaccines9020160

Schaeffer, K. (2020, April 8). Nearly three-in-ten Americans believe COVID-19 was made in a lab. *Pew Research Center*. https://www.pewresearch.org/short-reads/2020/04/08/nearly-three-in-ten-americans-believe-covid-19-was-made-in-a-lab/

Shaw, J., Anderson, K. B., Fabi, R. E., Thompson, C. A., Harris, M., Aljabbarin, N., Bolourchi, D., Mozo, N., Lichtenstein, D., Lupone, C. D., Larsen, D. A., & Shaw, A. V. (2022). COVID-19 vaccination intention and behavior in a large, diverse, U.S. refugee population. *Vaccine*, *40*(9), 1231–1237. https://doi.org/10.1016/j.vaccine.2022.01.057

Siddiq, H., Teklehaimanot, S., & Williams, J. (2024). An Observational Study Quantifying the Disproportionate Impact of COVID-19 Among Immigrant Adults, 2021 California Health Interview Survey. *Public Health Reports (Washington, D.C. : 1974)*, *139*(1), 120–128. https://doi.org/10.1177/00333549231208485

Strully, K., Yang, T.-C., & Liu, H. (2021). Regional variation in COVID-19 disparities: Connections with immigrant and Latinx communities in U.S. counties. *Annals of Epidemiology*, *53*, 56-62.e2. https://doi.org/10.1016/j.annepidem.2020.08.016

Sudhinaraset, M., Nwankwo, E., & Choi, H. Y. (2022). Immigration enforcement exposures and COVID-19 vaccine intentions among undocumented immigrants in California. *Preventive Medicine Reports*, *27*, 101808. https://doi.org/10.1016/j.pmedr.2022.101808

Sundaram, M. E., Calzavara, A., Mishra, S., Kustra, R., Chan, A. K., Hamilton, M. A., Djebli, M., Rosella, L. C., Watson, T., Chen, H., Chen, B., Baral, S. D., & Kwong, J. C. (2021). Individual and social determinants of SARS-CoV-2 testing and positivity in Ontario, Canada: A population-wide study. *CMAJ: Canadian Medical Association Journal = Journal de l'Association Medicale Canadienne*, *193*(20), E723–E734. https://doi.org/10.1503/cmaj.202608

Svallfors, S., Larsson, E. C., Puranen, B., & Ekström, A. M. (2023). COVID-19 vaccine hesitancy among first-generation immigrants living in Sweden. *European Journal of Public Health*, *33*(4), 687–694. https://doi.org/10.1093/eurpub/ckad073

Takayama, M., Wetmore, C. M., & Mokdad, A. H. (2012). Characteristics associated with the uptake of influenza vaccination among adults in the United States. *Preventive Medicine*, *54*(5), 358–362. https://doi.org/10.1016/j.ypmed.2012.03.008

Tanase, L.-M., Kerr, J., Freeman, A. L. J., & Schneider, C. R. (2022). COVID-19 risk perception and hoax beliefs in the US immediately before and after the announcement of President Trump's diagnosis. *Royal Society Open Science*, *9*(8), 212013. https://doi.org/10.1098/rsos.212013

Tankwanchi, A. S., Bowman, B., Garrison, M., Larson, H., & Wiysonge, C. S. (2021). Vaccine hesitancy in migrant communities: A rapid review of latest evidence. *Current Opinion in Immunology*, *71*, 62–68. https://doi.org/10.1016/j.coi.2021.05.009

Thurman, N. (2018). Newspaper Consumption in the Mobile Age: Re-assessing multi-platform performance and market share using "time-spent." *Journalism Studies*, *19*(10), 1409–1429. https://doi.org/10.1080/1461670X.2017.1279028

Watson, O. J., Barnsley, G., Toor, J., Hogan, A. B., Winskill, P., & Ghani, A. C. (2022). Global impact of the first year of COVID-19 vaccination: A mathematical modelling study. *The Lancet. Infectious Diseases*, *22*(9), 1293–1302. https://doi.org/10.1016/S1473-3099(22)00320-6

WHO. (n.d.). *Vaccines and immunization*. World Health Organization. Retrieved April 17, 2024, from https://www.who.int/health-topics/vaccines-and-immunization#tab=tab_2

WHO. (2024, April 9). *Hepatitis B*. https://www.who.int/news-room/fact-sheets/detail/hepatitis-b

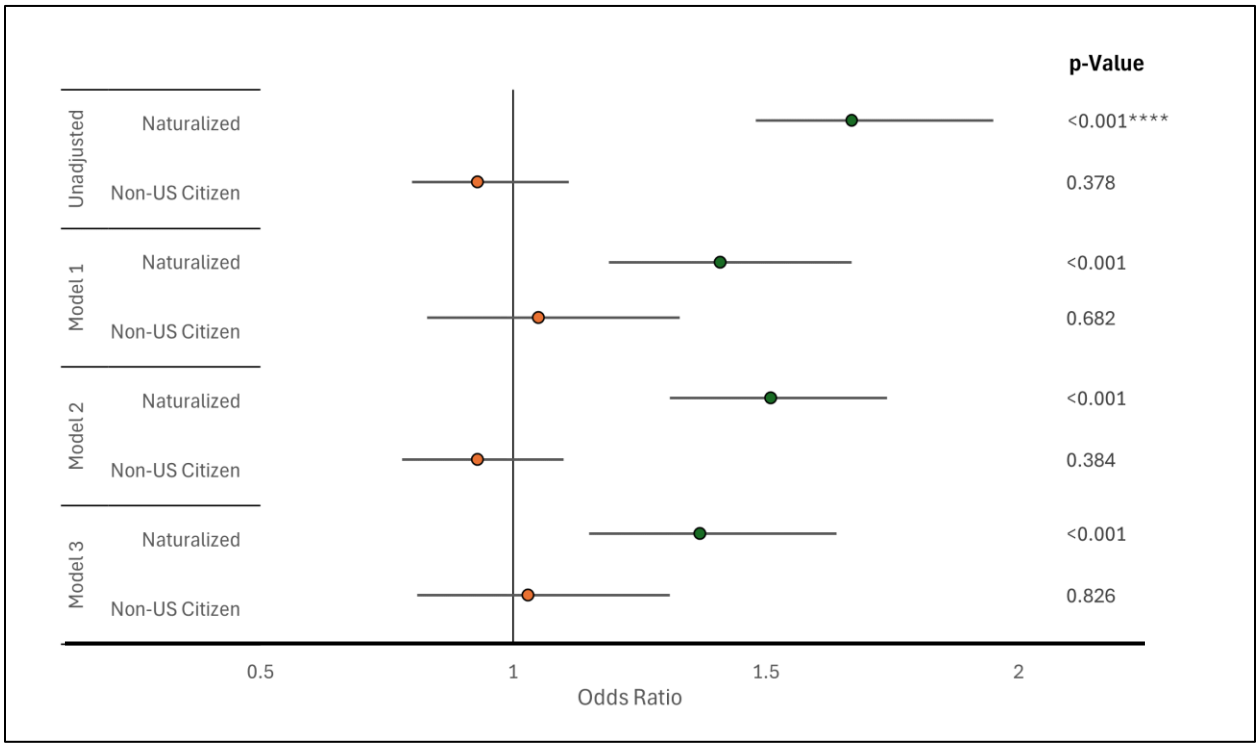
Wickramage, K., Gostin, L. O., Friedman, E., Prakongsai, P., Suphanchaimat, R., Hui, C., Duigan, P., Barragan, E., & Harper, D. R. (2018). Missing: Where Are the Migrants in Pandemic Influenza Preparedness Plans? *Health and Human Rights*, *20*(1), 251–258.

World Health Organization. (2018). *Report on the health of refugees and migrants in the WHO European region: No public health without refugee and migrant health*.

Yong, A. G., Lemyre, L., Farrell, S. J., & Young, M. Y. (2016). Acculturation in preventive health for immigrants: A systematic review on influenza vaccination programs in a socio-ecological framework. *Canadian Psychology / Psychologie Canadienne*, *57*(4), 340–355. https://doi.org/10.1037/cap0000075

Appendix

FIGURE 4: *Forest plot Analysis by Immigrant Status on COVID-19 Vaccination: Unadjusted to Adjusted Models.*



The forest plot displays the unadjusted and adjusted odds ratios (OR) for COVID-19 vaccination uptake among naturalized and non-US citizen across different models. Model 1 adjusts for demographic factors including length of residency, sex, age, diabetes status, and race; Model 2 adjusts for behavioral factors including health professional consultation, face cover usage, participation in large indoor gatherings, adherence to guidelines, and primary source of covid-19 information; and Model 3 represents the fully adjusted model for both demographic and behavioral factors. ORs greater than 1 indicate higher odds of vaccination, while ORs less than 1 indicate lower odds.