

Influenza Vaccination Among Pregnant U.S. Women, 2012-2020: A Qualitative Analysis

CB

Introduction

Background: Influenza virus infection represents a significant disease burden on pregnant women and infants in the United States (1). Pregnancy and infancy (under 1 year of age) are times of relative immunosuppression and vulnerability to certain types of infection (2). Influenza virus has long been recognized as particularly virulent in pregnant women (3, 4) with an increased risk for hospitalization, ICU admission, and death (5). During the 2009 H1N1 Influenza pandemic, pregnant women had a five times higher risk of death from Influenza virus infection and associated serious morbidities (such as *Staphylococcus aureus* pneumonia superinfection and acute respiratory distress syndrome) than the general population (6-8).

Immunization during pregnancy creates IgG antibodies that cross the placenta and enter fetal circulation where they remain for approximately six months (9, 10). Breastfeeding also transmits maternal antibodies that protect newborns from infections (9). Antibodies acquired in the pre- and peri-natal periods protect babies after birth until at least 6 months of age (11). This is critical because infants are not eligible for Influenza vaccination until 6 months old (12). Indeed, infants under 6 months old have the highest rates of hospitalization related to Influenza virus infection of any age group, including older adults. Rates are estimated at 4.5 hospitalizations per 1000 children (13), which given approximately 4 million babies born each year, translates to nearly 18,000 hospitalizations. In addition to the human costs of caring for a sick infant, this represents a multi-billion-dollar burden on the medical system, especially as these infections are compressed into the December-March timeframe ("Flu season") (47).

Prenatal exposure to maternal influenza infection is known to have a negative impact on long term childhood outcomes. Indeed, vaccination against influenza during pregnancy is associated with a reduced risk of preterm birth, small for gestation age status (indicating poor fetal growth), and low birth weight (less than 2500g or 5.5 pounds) at delivery (14-16). The strong associations between the above morbidities, especially prematurity, with worse long term neurodevelopmental outcomes, is well established (17-21). In addition to the above, several studies have found an association between Influenza infection during pregnancy (22-24), especially during the first trimester, and later development of autism spectrum disorders in offspring. Indeed, children conceived in the winter months (December-March, peak Influenza season) have a 6% increased risk of autism spectrum disorder. Similarly, schizophrenia, a devastating neuropsychological disorder that most often presents in early adulthood has been linked to first trimester prenatal influenza infection exposure with a 7-fold increased risk (25). Bipolar disorder has also been associated with prenatal Influenza infection exposure with a nearly 4-fold increased risk (26).

The yearly influenza vaccine has a long track record of safety and efficacy during pregnancy and is recommended by the Centers for Disease Control (CDC) and American College of Obstetrics

and Gynecology (ACOG) for all pregnant women (27, 28). The World Health Organization (WHO) recommends a minimum 75% vaccination rate among the population to protect those at highest risk for severe infection (29). In fact, the WHO considers pregnant women to be the highest priority Influenza vaccination group for countries initiating or extending Influenza vaccine efforts (29). It is well documented that the Influenza vaccine during pregnancy is effective, reducing proven Influenza virus infection in infants 0-6 months of age by up to 63% and in pregnant women by over 50% (11, 14). In the U.S., despite the strong recommendation by the CDC and the American College of Obstetrics to be vaccinated against Influenza, many pregnant women are not. This report examines influenza vaccine rates among pregnant women in the U.S. and looks at trends over time using qualitative analyses of publicly available data.

Research Questions: The objective of this report is two-fold: 1.To determine whether the Influenza vaccination rate for pregnant women is increasing or decreasing in the U.S., and 2. Examine factors associated with low and high vaccine uptake, looking at trends over time.

Identifying those pregnant women less likely to be vaccinated can help inform where efforts to promote vaccine utilization are needed most. Conversely, identifying where vaccination rates have recently improved may provide clues about where to look for examples of successful pro-vaccination public health campaigns.

Methods

Study Population: This data was acquired from the Centers for Disease Control website [view here](#). The study population was pregnant women 18-49 years of age, residing in the United States, who were pregnant anytime between August 1st and the survey date. Surveys were an internet panel national survey conducted at the end of Influenza Season (March-April). Sample sizes were between 32,000-47,000 per year.

Data Cleaning and Wrangling: Data was downloaded directly from the CDC website as a text file with comma separated variable datapoints. The years 2012-2020 were covered and vaccination rates for Influenza as well as Tdap were included. As my interest is Influenza vaccination, Tdap data was removed. New York City, Puerto Rico and the District of Columbia were also in the dataset, however I removed these as my interest is in the 50 U.S. states. The dataset did not report data on all 50 states for all years. In 2012, only 29/50 states had data. In 2020, 39/50 states had included data. Age group and race/ethnicity data were included in the dataset, with both national and by state information. The age and race/ethnicity data were reported separated (not within each subgroup with respect to the other variable) and thus were not able to be examined simultaneously (i.e. examining age group trends by race/ethnicity).

Missingness was examined as a whole and by variable. Overall, there were found to be 267 missing observations out of 2,470 (10.8%). Breaking this down by variable, I found that within the age group data, only 12 out of 1,244 observations were missing. As this only represented 1% of data points, these were removed. Within the race/ethnicity data, 255 out of 1,226 observations were found to be missing (20.1%). Separating out the missing values by national versus state data, it was found that all missing values were from state specific race/ethnicity data. Given the 20% missingness rate for this subset of the data, and likely introduction of inaccuracies with attempted imputation given variability in state participation in the survey each year, I decided to only examine race/ethnicity on a national level. A region variable was created using states by region specified on the CDC website (states were divided into West,

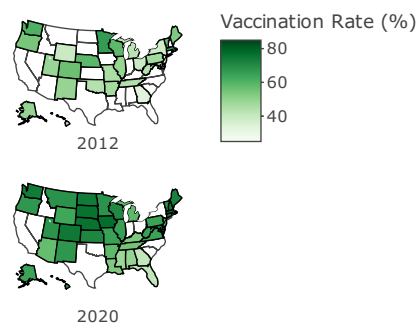
Midwest, Northeast and South). Duplicate rows were examined for and removed. Summary statistics were performed to check for implausible values and none were identified.

Software: Data analysis was performed using “R”, an open source data analysis tool (R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria [URL here](#). The following R libraries were used for data wrangling, analyses, graphs, and tables: Data.Table, dplyr, tidyverse, knitr, ggplot2, readr, plotly, DT. The code behind this website and accompanying PDF is published in full on my github repository [website source code](#) and [PDF source code](#).

Results

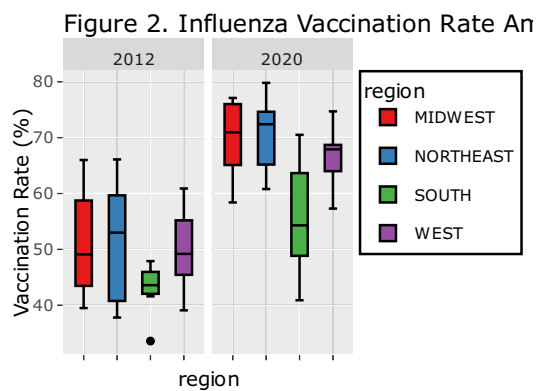
National – The Influenza vaccination rate among pregnant women in the U.S. is increasing. Despite not all states reporting for each year, a national overview between 2012 and 2020 (Figure 1) shows a clear increase over time. In 2012 the national vaccination rate for all women over the age of 18 was 47.4% (N=31, 507), and by 2020 it had increased to 61.1% (N=40, 339). This represents an increase nationally of 13.7%.

za Vaccination Rate During Pregnancy by State



Region - Next, Influenza vaccination rates were evaluated by region, comparing the year 2012 to the year 2020 (Figure 2). The Midwest region had the largest increase in median vaccination rate, starting at 49.1% in 2012 up to 70.95% in 2020, a nearly 22% increase. Conversely, the South had the lowest rate increase, from 43.6% in 2012 to 54.3% in 2020, a 10% change. All four U.S. regions had increased vaccine rates over time, with the Northeast having the highest rates (72.4% in 2020) and the South having the lowest (54.3% in 2020). In 2012 the vaccination rate in the Midwest region was below the Northeast and West, however in 2020 it overtook

the Western region with rates close to the Northeast by 2020 (Midwest vaccine rate in 2020, 70.95%).



States – Data was next examined at the individual state level. A line graph (Figure 3) showing each state by year reveals the two states with the lowest vaccination rate, Georgia, and Florida. Massachusetts and Iowa top the list of highest vaccinated states with 79.8% and 77.1% in 2020 respectively. Change in vaccination rate between 2012 and 2020 is examined in Table 1 by state. The states of Hawaii, Wyoming, Maryland, and New Jersey had the largest increases with 26.7, 24.2, 22.6, and 22.2 percent respectively. With 2012 rate around 40% in these states, now achieving vaccination rate above 60% represents a nearly 50% increase.

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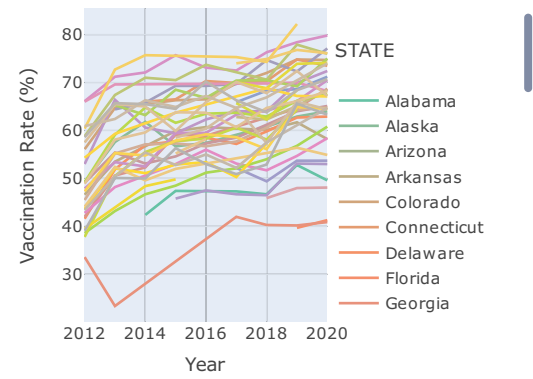
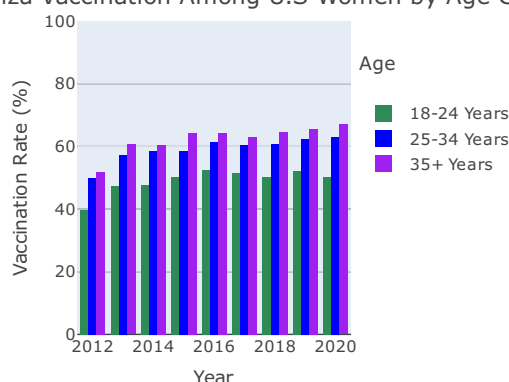


Table 1. Change in Vaccination Rate by State, 2012 to 2020 (Numeric values are percentages)

State Year: 2012 Year: 2020 Change

Age – Data was available for each of three age groups: 18-24 years, 24-34 years, and 35 years old and above. Nationally, women 35 years and older have the highest vaccination rates and those aged 18-24 years have the lowest (Figure 4, Table 2). In terms of change over time, pregnant women 35 years and older had a 15.2% increase in vaccination rate (from 51.8% to 67%). For women ages 24-34 years, vaccination rate has been relatively constant between 2016-2020, hovering in the low 60s percent range. This is also true for the youngest age group, women 18-24 years of age who have had vaccination rates in the low 50s since 2016. State specific data broken down by age group can be explored in Table 3.

Figure 4: Vaccination Among U.S. Women by Age Group



Ethnicity – Data was available for each of four race/ethnicity groups: “Black, non-Hispanic”, “Hispanic”, “White Non-Hispanic”, and “Other or multiple races, Non-Hispanic.” Data trends between 2012 and 2020 are demonstrated in Figure 5. Women in the Other or multiple races, non-Hispanic group had the largest increase in vaccination rate between 2012 and 2020, with a 21.3% increase (from 48.7% to 70%). This group overtook White, non-Hispanic women in 2014 and has had the highest Influenza vaccination rate since that time. White non-Hispanic women have also increased their rates by 16%, from 49.5% in 2012 to 65.5% in 2020. Black, non-Hispanic women have by far the lowest vaccination rate in all years examined. After an initial 14% increase in vaccination from 2012 to 2016 (36.1 to 50.4%), rates are decreasing among this group with a 2020 rate of 41.6%. Hispanic women are the next lowest group though have seen minimal change in yearly rate since 2015, hovering near 60%. Two interactive tables allow exploration of race/ethnicity data nationally (Table 2) and by state (Table 3).

Vaccination Among U.S. Women by Race/Ethnic

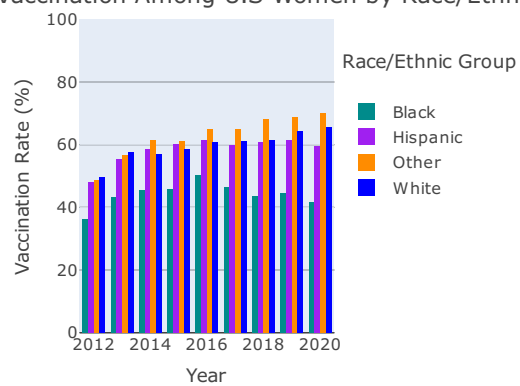


Table 2. Nationwide: Influenza Vaccination Rate Among Pregnant U.S. Women, 2012-2020

Year Age or Race/Ethnicity Vaccination Rate (%)

Table 3. By State: Influenza Vaccination Rate Among Pregnant U.S. Women, 2012-2020

State Year Age or Race/Ethnicity Vaccination Rate (%)

Discussion

Influenza vaccination among pregnant women is overall increasing in the United States. All four U.S. regions have higher rates in 2020 than 2012. However, there are subgroups of the population that have been slow to improve, have not made progress for many years, and are even decreasing in vaccination uptake. These are groups that would benefit from focused public health interventions.

The Southern U.S. continues to have the lowest vaccination rate in the country. This gap has widened between 2012 and 2020, from 6 to 15 percentage points lower than the next lowest region. This is likely a multifactorial phenomenon, however two of the most influential demographic characteristics that predict vaccination status are insurance (private vs public) and level of education (30). This dataset did not address these factors directly. However, the South is the U.S. region with the lowest rates of college completion (28.2% in 2021, versus the Northeast with 34.8%) (31), and highest rates of public insurance recipients (32). Indeed, access to medical care is a known barrier to vaccination in the general adult population (33). One promising intervention is education of providers and public health interventions that target medical clinics which have been quite effective in improving vaccination rates (34-36). Settings in which a provider can recommend and administer a vaccination at the same visit are particularly effective (34). These types of efforts, focused on the Southeast, especially Georgia and Florida have strong upward potential. These are large populous states where even a small improvement translates into many thousands of women and their children being protected.

As women get older, they are more likely to be vaccinated against influenza during pregnancy. Older women also had the largest increase in vaccination rate between 2012 and 2020 suggesting this demographic is a primary driver of increasing vaccination rates nationally. One potential basis for these trends is the average age of a first-time mother is increasing in the U.S. It was 21 years of age in 1972 and has risen to an average age of 30 as of 2022 (37). The percentage of total pregnancies that are to older mothers has also increased while those to the youngest has decreased (37). Interestingly, a strong predictor of maternal age at first pregnancy is level of education, specifically ascertainment of a college degree (38). Education level and maternal age are inextricably linked. Finishing a four-year degree leaves most people at age 22-23 years at time of completion and the costs of post-secondary education in the U.S are rising rapidly (39). Though not looked at directly in this dataset, education is a likely primary driver of the linear relationship between age and vaccine uptake. (For a closer look at these trends at the New York Times, featuring interactive maps on this subject, see [here](#)).

The race/ethnicity findings in this data demonstrate significant gaps in influenza vaccination between women who identify as Hispanic or Black, non-Hispanic versus White and “Other” ethnic categories. These disparities are likely reflective of socioeconomic inequality and reduced access to healthcare and educational opportunities in the U.S. (40-41). The COVID-19 pandemic shed a stark light on the how care is not equal between racial and ethnic groups (42). Troublingly, vaccination against influenza among pregnant women who identify as Hispanic, has not changed in many years, and for those who identify as Black, rates are in fact decreasing. These trends highlight the importance of community-specific public health outreach.

Limitations

There are some notable weaknesses of this dataset that limit available analyses. As noted in the methods, not all 50 states are included for each year of data. This reduces generalizability of national data as some states are more represented than others. Furthermore, due to lack of reporting of certain states, region data is less representative of the true vaccine rate. For instance, California is not reported in any year. Given that approximately 12% of the U.S. population lives in California, this is a significant limitation to accuracy. When examining by region, this problem is heightened as the state represents an even larger percentage of the population for the Western region. (The California Department of Public Health tracks influenza vaccination among pregnant women in the state using the Maternal and Infant Health Assessment, a statewide survey. For further information, visit their website [here](#) and their [PDF report](#), (see page 4, figure 4 for influenza details). The second most populous state in the U.S., and most populous Southern region state, Texas, is also missing from this dataset for all years except 2015 and 2016.

The reporting of age and race/ethnicity as separate vaccination rates is another limitation, as it prevents additional granularity within subgroups. For instance, it would have been illuminating to stratify data within age groups by race/ethnicity and vice versa to see in more detail the most and least vaccinated subpopulations. In addition, the race/ethnicity data by state had more than 20% of observations missing, limiting available examination of race/ethnicity trends by state and region.

Lastly, these data were collected by internet panel survey thus introduce self-report and recall bias limitations.

Conclusions & Summary

Influenza vaccination uptake among pregnant U.S. women is increasing, reaching over 60% in 2020. Despite this positive trend, vaccination rates remain suboptimal, well below the WHO recommended 75%. By region, the South is the least (54.3%) and Northeast the most (72.4%) vaccinated areas of the country. Women who are younger, and identify as Hispanic or Black, non-Hispanic are less likely to receive the influenza vaccine than women over the age of 35 who identify as either White or Other, non-Hispanic ethnic group. Reasons for these observations are multifactorial, and likely represent an interplay between levels of education, access to quality prenatal and preventative health care, and racial/ethnic socioeconomic disparities in the U.S (43-46).

Overall, the above data indicate that efforts to increase influenza vaccine uptake in pregnant women will benefit most from community-based outreach targeting younger women who identify as Hispanic or Black, non-Hispanic in the Southern U.S.

References can be found here: https://github.com/CBSC73/PM566-Final_Project/blob/main/references.pdf