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Hanleigh James 05/07/2021
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The Influence of County-Level Contextual Characteristics on COVID-19 Pandemic Vaccination Coverage in the United States, December 14, 2020–March 31, 2021

By

Hanleigh James

MPH

Epidemiology

Dr. Shivani Patel, PhD, MPH

Committee Chair

Umedjon Ibragimov, MD, MPH, PhD

Committee Member

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By

Hanleigh James

Bachelor of Biology
University of Alabama at Birmingham
2019

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

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Abstract

The Influence of County-Level Contextual Characteristics on COVID-19 Pandemic Vaccination Coverage in the United States, December 14, 2020–March 31, 2021

By Hanleigh James

Background: Deaths attributed to COVID-19 have disproportionately occurred in US counties with larger socioeconomically vulnerable communities. There is concern that vaccination coverage across US counties has not been commensurate with population vulnerability. This study estimated the associations between county-level contextual factors and vaccination coverage.

Methods: We focused on area-level characteristics acting as facilitators or barriers to vaccination uptake. The county was the unit of analysis. The study outcome was the percentage of county residents who have had at least one dose of the vaccine as of December 14, 2020, obtained from the CDC's COVID Data Tracker. For analysis, counties were divided into tertiles based on vaccination coverage. We merged county vaccination coverage with the 2018 AHRQ's database on Social Determinants of Health (SDOH). Five domains of SDOH factors were examined: demographic composition, economic factors, educational attainment, physical infrastructure, and healthcare context. A logistic regression model was estimated to determine the association between county SDOH and low vaccination coverage, defined as the lowest tertile of county vaccination coverage.

Results: Unadjusted and adjusted odds ratios were largely similar. The percentage of population who are not U.S citizens (OR=1.156, 95% CI=1.086,1.231) and average household size (OR=27.629, 95% CI=17.523,43.563) were positively associated with low vaccination coverage. The percentage of households with limited English speaking (OR=0.799, 95% CI=0.735,0.870), percentage of the population with some post-high school education (OR=0.962 , 95% CI=0.950,0.974), median household income (OR=0.985, 95% CI=0.975,0.995), shortage of primary care physicians (OR=0.890, 95% CI=0.796,0.996), and number of facilities (OR=0.983, 95% CI=0.971,0.996) were inversely associated with low vaccination coverage.

Discussion: We identified several correlates of county-level COVID-19 vaccination coverage during the first phase of the vaccine roll-out. This information may be used to identify and address barriers and facilitators for vaccination uptake to ultimately improve coverage of the vaccine in vulnerable communities to reduce inequities in disease burden.

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Introduction

Coronavirus disease (COVID-19) is an infectious disease caused by a newly discovered coronavirus (WHO, 2021). It is a respiratory disease caused by SARS-COV-2, a new coronavirus that surfaced in 2019 (WHO, 2021). The virus is spread from person to person through respiratory droplets produced when an infected person coughs, sneezes, or talks (WHO, 2021). Adults 65 years or older and people of any age with underlying medical conditions are at higher risk for severe illness (WHO, 2021). On March 11, 2020, the World Health Organization (WHO) declared COVID-19 a pandemic, and it has become one of the deadliest pandemics in the last century. Since January, cases have increased to an estimated 140 million cases and 3,003,794 deaths (WHO, 2021). The burden of COVID-19 extends beyond that of a contagious disease, and it became a worldwide health crisis with drastic social, economic, and health consequences.

The urgent acceleration of SARS-Cov-2 vaccination prioritized individuals aged 65 and older in the U.S, who account for approximately 80% of deaths from COVID-19. The current U.S vaccination strategy does not prioritize equity; these disparities increase the coverage gap, and they reduce the effectiveness and control of the pandemic. The transmission of SARS-CoV-2 infection is patterned by place, which is shown by maps with unequal distributions of COVID-19 cases and deaths. Prioritizing communities, disproportionally affected, should be a part of the national strategy to reduce illnesses associated with COVID-19. COVID-19 has disproportionately impacted communities that are disadvantaged at social, economic, and environmental levels, and achieving high and equitable vaccination coverage should be a goal for maximizing the benefits of the vaccine. Inequities in the social determinants of health affecting these groups are interrelated and influence a wide range of health and quality-of-life outcomes

and risks. The commitment to receive vaccines from communities does not play as significant of a role as the social determinants that act as barriers to hinder access to those vaccinations. However, the reduction to those barriers is positively correlated to an increased commitment of communities to receive vaccines. The heterogeneity across different communities is associated with the environment, access, economic, and social aspects that contribute to the difference in vaccination coverage. Without an explicit focus on equity in a vaccination strategy, these COVID-19 disparities will certainly widen due to structural barriers limiting accessibility to vaccines among those most affected.

In the context of equitable vaccine coverage, the literature has focused on two types of issues: equity across nations, with emphasis on -income countries; and equity and other coverage issues in childhood immunizations (Koenig M, et al, 2001) (Mitchell, S., et al, 2009). Due to their burden of vaccine-preventable diseases, LMICs have been at the forefront of research to answer questions and problems associated with vaccination. Immunization of children has repeatedly been shown to be a cost-effective way to reduce vaccine-preventable diseases and promote health equity. Scholarly interest in the relationship between the social determinants of health on childhood vaccination and their relationship to inequities has increased over the years. The literature on adult vaccination in high-income countries, such as the United States, is limited.

This study will estimate the area-level associations of population and contextual factors with vaccination coverage. By highlighting specific population and contextual factors, this study will provide more insight to areas that require more aggressive efforts for equitable vaccine administration. This study will investigate the association between social determinants of health and county-level coverage the COVID-19 vaccine. This will quantify the magnitude and

geographical disparities in population-level COVID-19 vaccination uptake at the county level, which is important in addressing social and structural barriers limiting accessibility to vaccines.

Methods

We conducted an ecological analysis of social determinants of health variables and population vaccination coverage across U.S. counties. The unit of analysis for this study was the county.

Study Outcome

The proportion of the population in each county having at least one dose of the vaccine was the primary outcome. The outcome variable was computed as the number of adults over the age of 18 who had received the vaccine divided by the number of residents over the age of 18 in each county.

County-level vaccination data were obtained from the CDC's COVID Data Tracker from December 12, 2020, to March 31, 2021. Vaccination providers collect data on COVID-19 vaccine doses they administered and report the data to CDC through multiple sources, including jurisdictions, pharmacies, and federal entities by each state into local Immunization Information Systems (IISs). Daily reports include total counts of COVID-19 vaccinations, and vaccinations per 100,000. The U.S. Census Bureau Population Estimates are used to compute the county denominator. CDC excluded from county-level summary measures vaccination records missing county of residence.

Study Exposures

Five key social determinants of health (SDOH) domains were considered in this analysis: social context, economic context, education, physical infrastructure, and healthcare context. County-level measures for these domains were obtained from the 2018 Agency for Healthcare Research and Quality's (AHRQ) database on SDOH. These SDOH beta data files were curated from 17 existing Federal datasets and other publicly available data sources.

The indicators for this study came from the US Census American Community Survey (ACS) and Area Health Resource Files (AHRF), which compiles data from more than 50 databases and other sources on healthcare professions, health facilities, population characteristics, economics, health professions training, hospital utilization, and hospital expenditures. Variables for this study related to healthcare professionals were selected from this source.

The county characteristic variables were categorized by demographics, education, living conditions and transportation, connectivity, income, and access. We included the percentage of non-United States citizens, the percentage of households with limited English speaking (mainly speaking Spanish, Indo-European languages, Asian and Pacific Islander), the percentage of the population that is female, the percentage of the population with any postsecondary education attainment for the population (aged 25 and over), percentage of housing units with no vehicle available, percentage of households with any internet connection, median household income, and average household size. Health Professional Shortage Area (HPSA) variables include shortage of primary care physicians, number of nurse practitioners with national provider index, number of physician assistants with the national provider index, and number of health facilities..

Statistical Analysis

Descriptive statistics were calculated for the county characteristics, where continuous variables were reported as mean and standard deviation, and binary and categorical variables were reported as percentages. Counties were classified into one of three tertiles based on population vaccination coverage: low (0-12.9%), moderate (12.9-17.1%), and high (17.1-100%).

Descriptive statistics for each county exposure were computed for each of the vaccine coverage tertiles.

Logistic regression was used to estimate the odds ratio (OR) and 95% confidence intervals (CI) describing the association between county contextual characteristics and low SARS-Cov-2 vaccination coverage. Low vaccination coverage was defined as counties in the lowest tertile of vaccination coverage (reference= moderate and high tertiles). Unadjusted associations between each of the county characteristics and low vaccination coverage were modeled separately. Fully adjusted models included all the county characteristics simultaneously. We performed statistical analyses using SAS (version 9.4; SAS Institute), and p-values <0.05 were considered statistically significant.

Results

We analyzed data from 2694 U.S. counties. The distribution of county characteristics across U.S., and the distribution of county characteristics stratified by levels of population vaccination coverage, is presented in Table 1. Across counties, an average of 2.4% residents were not U.S. citizens, and 1.5% were lived in households with limited English speaking. 52.7% acquired some post-high school educations. The average county-level household income was reported to be $51,668. The county-level mean household size was 2.5 people. 73.9% of county residents had any type of internet connection. There was an average of 5.5 facilities, 1.5 primary care physicians, 84.5 physician assistants, and 44.5 nurse practitioners.

Counties were classified into tertiles of low (0-12.9%), moderate (12.9-17.1%), and high (17.1-100%) population vaccination coverage. The average percentage of the population who were not U.S. citizens (2.7%) was higher in county areas of low vaccination coverage compared to county areas of moderate (2.3%) and high (2.3%) vaccination coverage. An average of 49.6% of county residents had some post-high school education in low vaccination counties compared to 56.4% of the population in high vaccination counties. 6.2% of households in low vaccination coverage counties did not have a vehicle, while an average of 5.9% of households did not have a vehicle in high vaccination coverage counties. 71.7% of households had internet connection in low vaccination coverage counties, while 76.2% of households had internet connection in high vaccination coverage counties. Counties with low versus high vaccination coverage had lower average number of facilities (1.5 vs. 1.6) and lower average number of physician assistants (27.9 vs. 49.4). However, the average number of physician assistants (56.3) were highest average in areas with moderate vaccination coverage. Counties with low vaccination coverage had lower

median income ($49,573.73) compared with counties with high vaccination coverage ($54,360.37).

Table 1. Descriptive statistics for county-level social determinants of health characteristics overall and by county-level vaccination coverage (N = 2694)

Vaccination Tertile Levels		**Low Vaccination Coverage Estimate**	**Moderate Vaccination Coverage Estimate**	**High Vaccination Coverage Estimate**
Characteristics	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Demographics				
%Population who are not U.S. citizens	2.4% (3.1)	2.7% (3.6)	2.3% (2.9)	2.3% (2.8)
%Households with limited English speaking *	1.5% (2.3)	1.6% (2.5)	1.4% (2.3)	1.4% (1.9)
%Population that is female	50.0% (2.2)	49.8% (2.6)	50.2% (1.8)	50.0% (2.1)
Education				
%Population with some post high school education (ages 25 and over)	52.7% (10.6)	49.6% (11.3)	52.2% (9.9)	56.4% (9.5)
Living Conditions and Transportation				
Average Household Size	2.5 (.2)	2.6 (0.3)	2.5 (0.2)	2.4 (0.2)
%Housing units with no vehicle available	6.2% (3.56	6.2% (3.6)	6.5% (3.5)	5.9% (3.6)
Connectivity				
%Households with Any Internet Connection	73.9% (8.9)	71.7% (9.9)	73.8% (8.7)	76.2% (7.4)
Income				
Median household income	$51,668.6 ($13,581.9)	$49,573.73 ($14,483.67)	$51,150.60 ($12,515.48)	$54,360.37 ($12,945.74)
Access				
Shortage of Primary Care Physicians	1.5 (0.7)	1.5 (0.7)	1.6 (0.7)	1.6 (0.7)
Number of Nurse Practitioners with National Provider Index	44.5 (150.1)	54.5 (172.0)	108.4 (344.4)	89.7 (239.4)
Number of Physician Assistants with the National Provider Index	84.5 (263.2)	27.9 (101.1)	56.3 (185.2)	49.4 (150.3)
Number of Facilities	5.5 (12.3)	3.6 (5.8)	6.9 (17.7)	6.1 (9.6)

**Vaccination coverage is defined as the proportion of the county population that has received at least one vaccine dose of the SARS-Cov-2 vaccination between December 12, 2020- March 31, 2021

* Household language of limited English speaking households: Spanish speaking household, Other Indo-European languages speaking household, Asian and Pacific Island speaking household, Other language(s) speaking household

Table 2 shows factors associated with low vaccination coverage across counties. Associations in unadjusted and adjusted models were largely similar. In the adjusted models, counties with a one percentage point higher population who were not U.S. citizens had a high relative odds of low vaccination coverage (aOR=1.156, 95% CI=1.086,1.231). Counties with a one percentage point higher population with limited English-speaking households had a lower relative odds of low vaccination coverage (aOR=0.799, 95% CI=0.735,0.870). We observed no association between the percent of the population that is female and low vaccination coverage. Counties with a one percentage point higher population with some post-high school education had a lower relative odds of low vaccination coverage (aOR=0.962, 95% CI=0.950,0.974). Average household size showed a strong positive association with low vaccination coverage in the adjusted model (aOR=27.629, 95% CI=17.523,43.563). There was an inverse association between low vaccination coverage and housing units with an internet connection (aOR=0.992, 95% CI=0.976,1.008). We observed no association between median household income and low vaccination coverage in the adjusted model. The adjusted model (OR= 0.890, 95% CI=0.796,0.996) shows lower odds of vaccination coverage associated with the shortage of primary care physicians. We observed no association between the number of nurse practitioners or the number of physician assistants with low vaccination coverage. The model shows lower odds of vaccination coverage associated with number of facilities (OR=0.983, 95% CI=0.971,0.996).

Table 2. County contextual characteristics associated with low SARS-Cov-2 vaccination coverage between December 12, 2020 – March 31,2021 based on logistic regression analysis (N = 2694)

Characteristics	**Unadjusted Odds Ratio**	**Adjusted Odds Ratio**
	(OR, 95% CI)	(OR, 95% CI)
Demographics		
% Population who are not U.S. citizens	1.028 (1.005,1.052)**	1.156 (1.086,1.231)**
% Households with limited English speaking	1.031 (1.000,1.063) **	0.799 (0.735,0.870)**
% Population that is female	0.968 (0.938, 1.000)	1.001 (0.963,1.041)
Education		
% Population with some post high school education (ages 25 and over)	0.953 (0.946,0.959)**	0.962 (0.950,0.974)**
Living Conditions and Transportation		
Average Household Size	10.206 (7.358, 14.156)**	27.629 (17.523,43.563)**
% Housing units with no vehicle available	1.015 (0.995,1.035)	0.99 (0.96,1.02)
Connectivity		
% Households with Any Internet Connection	0.957 (0.950,0.965)**	0.992(0.976,1.008)
Income		
Median household income	0.980 (0.975,0.985)**	0.985 (0.975,0.995)**
Access		
Shortage of Primary Care Physicians	0.882 (0.797,0.975)**	0.890 (0.796,0.996)**
Number of Nurse Practitioners with National Provider Index	0.997 (0.994, 0.999)**	1.008 (1.000,1.016)**
Number of Physician Assistants with the National Provider Index	0.999 (0.999,1.000)**	1.001 (1.00,1.002)
Number of Facilities	0.987 (0.979, 0.995)**	0.983 (0.971, 0.996)**

**$p < 0.05$;

**Vaccination coverage is defined as the proportion of the county population that has received at least one vaccine dose of the SARS-Cov-2 vaccination between December 12, 2020- March 31, 2021

* Household language of limited English speaking households: Spanish speaking household, Other Indo-European languages speaking household, Asian and Pacific Island speaking household, Other language(s) speaking household

Discussion

In this analysis, counties with more social vulnerabilities, including those with a higher percentage of non-U.S. citizens and larger household size, had higher relative odds of low vaccination coverage. Counties with an increased percentage of households with limited English speaking, percentage of the population with some post-high school education, percentage of households with no vehicle available, percentage of households with any internet connection, shortage of primary care physicians, and the number of facilities has a lower relative odds of low vaccination coverage. In addition, number of nurse practitioners, and percentage of the population that is female were not associated with low vaccination coverage. These findings have implications for efforts to assist counties with identified social vulnerability to improve COVID-19 vaccination coverage, including prioritizing vaccination access and implementing public health action in counties.

Consistent with prior literature, these results show that several county attributes are associated with low vaccination coverage (Dasgupta S, 2020). The association between social vulnerability index (SVI) and hotspot detection was exemplified in county-level data on the COVID-19 study (Dasgupta S, 2020). Similar to the work by Dasgupta et al, our study's results show low vaccination coverage disproportionately affects communities of a higher social vulnerability. These circumstances could put vulnerable communities at increased risk for COVID-19 and reduces the effectiveness of the intended nationwide vaccination expected outcome. Incorporating the needs of populations that are socially vulnerable into community mitigation plans is essential for limiting COVID-19 transmission.

Our study found that counties with a one percentage point higher population who were not U.S. citizens had a high relative odds of low vaccination coverage. A similar study assessing the unadjusted association between vaccination coverage among foreign-born respondents showed U.S.-born respondents' vaccination coverage was significantly higher than that of foreign-born respondents (Lu, P. J ., et al, 2012). Low vaccination coverage has been associated with citizenship, which is often used as a proxy variable for nativity status. After arrival in the United States, many foreign-born adults experience socioeconomic, linguistic, and cultural barriers to accessing health care and preventative services. (Lu, P. J., et al, 2012). These barriers contribute to the disparities in vaccination coverage among non-U.S. citizens. Disparities were shown in influenza and pneumococcal immunizations among older adults for those primarily speaking Spanish at home (Lu, P. J., et al, 2012). Citizenship serves as a barrier to healthcare access (Lu, P. J., et al, 2012). As the U.S. population becomes more diverse of the foreign-born population, the findings from this study will be important in addressing COVID-19 vaccination inequities. Those disparities are even more relevant because immigration is projected to become the principal driver of U.S. population growth.

By contrast, there was an inverse association between the county-level proportion of residents with limited English speaking, and low vaccination coverage in this study. Previous studies have shown that linguistic barriers are experienced among populations that have limited English speaking, and this was shown to be true among Spanish speaking populations(Lu, P. J., et al, 2012). Given the relationship between citizenship and limited English speaking, it was anticipated to observe similar results for both variables, but given the urgency of the COVID-19 pandemic, the need to ensure effective communication among populations that are limited in their English speaking was a priority. Outreach and communications towards testing and

vaccinations have prioritized populations that may face language barriers, and this has contributed to vaccination uptake. Prior work in global settings has emphasized the importance of education and promoting health awareness (Sundaram, N. et al, 2013). This finding shows efforts to ensure proper knowledge of the vaccine and builds the trust that drives vaccination uptake, and specific attention has been made to households with limited English speaking during the COVID-19 pandemic. Nevertheless, it is important to ensure prioritization of vaccination information to non- U.S. citizens, as well.

The socioeconomic inequalities related to post-high school education show lower odds of low vaccination coverage. This finding from our study indicates that higher education contributes to increased vaccination coverage. A systematic review article examined literature that assessed the association between socioeconomic status (SES) and influenza vaccination, and of the 42 articles included in the review, 52.4% (n=22) resulted in higher levels of SES resulted in higher levels of influenza vaccination, 4.5% (n=2) reported a negative association, 14.3% (n=6) reported no association and 26.2% (n=12) found mixed results (Lucyk, K, et al, 2019). Over half of the reports resulted in an association with vaccination and higher levels of SES, and very few of the reports found a negative association. Also, higher educational attainment was identified as a predictor associated with vaccine acceptance and uptake in more urban communities compared to rural communities (Sundaram, N. et al, 2013). Populations with low SES tend to reside in more remote areas where vaccines are not as accessible, and as found in this study, this results in lower vaccination coverage. In previous studies related to pediatric immunizations, parental education was associated with the low vaccination of their children (Morrow AL, et al, 1998) (Vo, H. L, et al, 2019). These findings show the similarity of the association between education level and vaccinations in adults and children, which suggests the

high level of impact that should be addressed as a barrier to vaccinations because of the association across all age groups. Because the COVID-19 vaccinations have been a free health service, the financial costs of receiving the vaccine are not explanatory to these findings. However, the financial burden of job insecurity and financial freedom can have an impact on the ability to receive vaccines. Low-wage workers have the less financial freedom to miss work to receive the vaccine. Because of the symptoms that may result from the vaccine, it may keep them from work for an extended period. While employers are flexible in allowing employees to take time off to get vaccinated, there is no regulation to ensure the time off is paid. Unpaid time off can cause financial hardship. In addition, people with low SES are more likely to live in areas where health facilities are not in close proximity, which is also supported by our findings showing the number of facilities that have a lower odds of low vaccination coverage (Sundaram, N. et al, 2013). Increasing the number of facilities to areas where fewer facilities are available would increase access to vaccination, and conducting targeted outreach in counties that have lower socio-economic status could increase the opportunity to receive vaccines. Also, implementation of a policy that ensures paid time off or other incentives to receive the COVID-19 vaccine could aid in reducing the financial burden.

Average household size showed a strong positive association with low vaccination coverage. Household size has been shown to have an impact on the disease infection rate. The larger the household size (>2 persons) the greater the rate of attack from frequent contact with people in a single household. Few works of literature have shown the association with household size and low vaccination coverage. Other literature addresses the financial impact of larger households (Danis K, et al, 2010). A study done in Athens, Greece investigated predictive factors to immunization among children (Danis K, et al, 2010). This study used a similar analysis

strategy by using logistic regression, and the results concluded a negative association with household size with more than two children and immunizations (Danis K, et al, 2010). As previously discussed, socioeconomics plays a role in immunization uptake. As the family size increases, the demand for resources and finances increases; therefore, larger family sizes face a financial strain. These findings suggest a need to target larger households in interventions to increase vaccination coverage.

Internet has played an increasing role in connecting people to health information that drives vaccine uptake. Our study showed that households with internet connection had a low relative odds of low vaccination coverage. In more recent studies, researchers have investigated the role of text messaging and immunization campaigns to increase vaccination coverage. Text messaging and email usage has found to be a convenient and low cost way to communicate to in the field of immunizations (AmiciziaD et al, 2013)(Cooney F et al, 2010). The use of internet and the media are increasingly accessible to the general population (ThompsonHS et al, 2013). There is some evidence that internet or interactive computer-based health education programs in breast cancer patients increase health knowledge. These findings suggest they offer great potential to increase vaccine uptake and immunization coverage because of their convenience to communicate to the public and the accessibility of readily available information.

Inadequate healthcare infrastructure, including the shortage of primary care physicians, contributes to the ongoing disparities in vaccination coverage. Our study found the higher number of primary care physicians was associated with the lower odds of low vaccination coverage. Primary care physicians are essential to ensuring that vaccines reach all patients that need them, so health provider shortages are an important factor when explaining low vaccination coverage. Few publications address the shortage of vaccine providers; however, one study

addressed the geographic distribution of vaccine providers to increase HPV (Shah, P. D., et al, 2018). This study used the same measure for the shortage of primary care physicians through the Primary Care Health Professional Shortage Areas (HPSA) (HPSA, 2017), and the largest disparities in the HPV vaccination and physician coverage in Texas were due to geography (rural vs. urban) (Shah, P. D.,2018). The study concluded that after adding pharmacists to the workforce, there would be an increase in the availability of vaccine providers in areas with inadequate primary care providers (Shah, P. D., et al, 2018) This would increase vaccination coverage. Similar to our study, this study associates the shortage of primary care physicians as a barrier to vaccinations. Physicians are health care experts, and they are responsible for providing information on the risk of disease and overall wellbeing. The shortage of physicians reduces available staff able to administer vaccines. Other literature suggests that physicians spatially cluster due to physician networks and financial gain, which causes shortages in other areas (Shah, P. D., et al, 2018) (Porter ME, et al, 2013). As the demand for vaccines increases, the need for adequate physicians in areas to administer vaccines will also increase. From our study and literature, we can support the need for the recruitment and training of other medical professionals to administer vaccines is necessary to manage the needs of the pandemic.

Our study results found that the number of facilities was associated with a lower odds of low vaccination coverage. These results suggest that the number of facilities results in an improvement in vaccination coverage. These results are consistent with literature that has documented the association of children failing to receive healthcare services due to not having a primary medical facility to receive health services. Similarly, a study conducted an assessment of the effectiveness of The Vaccines for Children (VFC) program was designed to reduce the cost of vaccines for vulnerable children to determine how having a medical home was associated with

vaccination coverage (Smith PJ, et al, 2005). The study used the National Immunization survey method. Although the vaccination coverage rate among VFC-eligible children who had a medical home and received all vaccine doses from their medical home was essentially equivalent to that of non-VFC-eligible children, substantial percentages of VFC-eligible children either did not have a medical home or did not use their medical home to receive all of their recommended vaccinations (Smith PJ, et al, 2005. The vaccination coverage rate among these children was significantly lower (Smith PJ, et al, 2005). Failure to access preventive services that require multiple timely visits to the health facility is correlated. This correlation suggests an opportunity for vaccination barriers by increasing the number of facilities providing vaccination services. Having a regular health facility has been commonly associated with the increased likelihood of receiving recommend health services (Hayward, R. A., 1991). Low vaccination coverage can be explained by the limited access to health facilities. Some studies have shown that access to health facilities can be contributed to a lack of insurance; however, this is not relevant to the COVID-19 pandemic because of the free vaccination services provided. Previous studies have also found the lack of access to health facilities was a result of a lack of transportation. Our study found that the percentage of households with no vehicle available was associated with lower odds of low vaccination coverage, but it was not statistically significant. Therefore, we can not conclude that the households without vehicle access and low vaccination coverage are correlated. In the future, geospatial analysis of the health facilities should be investigated to understand the geographic placement of facilities, and eventually, increase the number of facilities of targeted outreach services to areas with fewer health facilities.

Counties with a higher percentage of non-U.S. citizens and larger household sizes were found to be associated with low vaccination coverage. This indicates an urgent need to prioritize

public health action to increase vaccination coverage, especially in areas with a higher percentage of non-U.S. citizens. Also, target outreach to address barriers faced with larger households. Findings also showed low relative odds in low vaccination coverage across a percentage of households with limited English speaking, household income, number of primary care physicians, number of facilities, and percentage of the population with some post-high school education. This information is valuable in understanding variables that contribute to increased vaccination uptake. It is encouraged to increase support in developing and implementing strategies to increase COVID-19 vaccination coverage and limit further COVID-19 cases and transmission.

The study was limited by only estimated ecological associations, and it did not include individual-level data. Also, vulnerabilities may vary within each county. Further analysis should conduct analysis in smaller geographic units, such as zip code level. This study also did not include all county-level contextual characteristic that could potential be associated with low vaccination coverage. One of the strengths of the study is the large sample size. This study estimated county-level contextual factors across all U.S. counties.

Conclusion

Given the lifesaving potential of -vaccines for COVID-19, it is important to tailor and prioritize strategies that facilitate reaching vulnerable populations. By identifying different county-level indicators, this investigation provides a more detailed view of vaccination barriers. The study findings show counties with more social vulnerabilities, including those with a higher proportion of non-U.S. citizens, larger household size, lower household income, lower number of primary care physicians, lower number of nurse practitioners, and fewer number of facilities, have lower vaccination coverage on average. Findings from this study highlight the importance

of ongoing monitoring of the county-level metrics, and the results emphasize the need for further analysis at the sub-county-level for a more in-depth analysis, including geospatial analysis. Stratification by these county-level indicators would provide more information on specific populations that are more disproportionately impacted by vaccination inequities.

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