



Mpox Vaccination and the Role of Social Vulnerability in Durham County, North Carolina, USA

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Abstract

Background Disparities in vaccine coverage among groups in the USA is common, possibly due to higher vaccine hesitancy in certain populations, difficulty accessing vaccines, and underlying social vulnerability.

Methods The aim of this study was to investigate the association between mpox vaccine administration, social determinants of health, and social vulnerability index (SVI) in Durham County, North Carolina, USA. Random forest regression (RFE) and min–max scaling preprocessing were used to predict mpox vaccinations in Durham County at the census tract level. The top eleven most influential features and their correlations with mpox vaccination were calculated.

Results Non-Hispanic white individuals, males, and those between the ages of 20 and 40 years were overrepresented in mpox vaccine reception in Durham County. Surprisingly, lacking a high school diploma, lacking health insurance, lacking a household vehicle, and living below the poverty line were all positively associated with receiving the mpox vaccine. Being a Black or African American and Hispanic or Latino individual was also positively associated with receiving the mpox vaccine.

Discussion Vaccine outreach efforts in Durham County, North Carolina, had success in reaching at-risk individuals, including socially vulnerable individuals. Future research should focus more specifically on how social vulnerability relates to vaccine reception for vaccine-preventable diseases.

Keywords Mpox · Jynneos · Vaccines · Social determinants of health · Social vulnerability index · Vaccine inequity · Health inequity

Introduction

Mpox, previously referred to as monkeypox, is a viral zoonotic infection caused by the mpox virus. Endemic to Central and West Africa, the mpox virus has caused sporadic outbreaks in countries in this region such as Nigeria [1] as well as outbreaks in non-endemic settings including the USA. These outbreaks have typically been related to travel from endemic areas, including in returning travelers from Nigeria to the UK [2], Israel [3], and Singapore [4]. A

large outbreak involving 71 cases in the USA in 2003 was linked to the importation of Gambian giant rats and dormice from Ghana, which infected prairie dogs in Illinois and subsequently humans [5]. On May 7, 2022, a case of mpox infection was confirmed in an individual in the UK who had recently traveled to Nigeria [6], followed closely by the first case of mpox infection diagnosed in the USA on May 17, 2022 [7]. As of June 21, 2023, over 88,000 cases of mpox infection were diagnosed in 111 countries globally, with the vast majority of cases diagnosed in countries where mpox traditionally has not been endemic [8]. Of these infections, over 30,000 cases were diagnosed in the USA [9].

Approved by the Food and Drug Administration (FDA) in September 2019, the 2-dose Jynneos vaccine is the only FDA-approved vaccine to specifically prevent mpox disease [10] and is highly effective in preventing infection. The major obstacle at the onset of the 2022 mpox outbreak was a shortage of Jynneos vaccine. Thus, vaccination was only offered to those individuals thought to be at the highest risk

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of developing mpox infection, such as men who have sex with men (MSM), bisexual, and transgender individuals. In addition, dose-sparing regimens were considered by some health officials, and an intradermal dosing strategy utilizing only a fraction of the standard subcutaneous dose was widely implemented [11].

Particularly considering the widespread shortage of Jynneos vaccine early in the mpox pandemic, inequities in vaccine access—as were seen during the COVID-19 pandemic—were a significant concern [12]. These concerns proved prescient across the US, Black or African American, and Hispanic or Latino populations were overrepresented in mpox infections and underrepresented in mpox vaccine administration [13]. For example, in North Carolina, USA, while 60% of Jynneos vaccines were administered to non-Hispanic white individuals, only 27% went to Black or African American individuals, yet 67% of mpox infections were diagnosed in Black or African American individuals [14].

Whether these vaccine inequities were due to vaccine hesitancy in certain populations, barriers to access the Jynneos vaccine, or other causes is unclear. Durham County is one of the most diverse counties in North Carolina with less than 50% of the population consisting of non-Hispanic whites [15]. Black or African Americans make up 35.3% and Hispanic or Latinos make up 13.9% of the population. While a racially diverse community has many advantages, inequities persist in these populations due to structural and systemic racism.

To better understand possible underlying causes for mpox vaccine disparities, the DCoDPH analyzed Jynneos vaccine administration in the context of underlying social determinants of health (SDOH) from the 2022 American Community Survey and the social vulnerability index (SVI) [16]; the latter is a tool that captures social factors and external stressors that may impact human health. Our goal was to better understand the association between underlying SDOH, social vulnerability, and mpox vaccine reception in Durham County, North Carolina, USA.

Materials and Methods

Basic demographic information including age, sex, race, and ethnicity from vaccine records of Jynneos administration was analyzed from the Durham County Department of Public Health (DCoDPH). Data collected from August 8, 2022, to January 18, 2023, was used in this analysis. Data used in this paper came from the 2022 American Community Survey (ACS) and mpox vaccine records from the Durham County Department of Public Health (DCoDPH). The data was analyzed at the census tract level which is a geographically compact area, often smaller than a county and zip code, and is designed to capture the local neighborhood

characteristics. The goal was to capture patterns and relationships within these local neighborhood levels.

Predictive modeling is an essential tool for understanding complex relationships among variables in large datasets. Random forest regression (RFE) and min–max scaling preprocessing were used to predict the dependent variable (mpox vaccinations in Durham County). First, the min–max scaling was used to normalize the feature values to a specific range (0 to 1), ensuring equal contribution from all features in the predictive model. Min–max scaling is given by the following formula: $x_{\text{scaled}} = (x - x_{\text{min}}) / (x_{\text{max}} - x_{\text{min}})$, where x is the original value and x_{scaled} is the normalized value [17]. Second, random forest regression model was used due to its robustness and ability to handle nonlinear relationships between features. Random forest regression is an ensemble of decision trees. This means instead of relying on a single tree to make predictions, multiple trees were built to determine the outcome.

The model in total used 77 various SDOH as well as all the variables found in the SVI [18]. The importance of each feature was computed using the Gini importance or mean decrease in impurity (MDI) [19], which measured the average decrease in how it quantifies how dissimilar the data points are at a particular node due to splits and not a particular feature, averaged over all trees in the forest. The model's performance was evaluated using several error metrics, including the mean square error (MSE) of 0.0077, mean absolute error (MAE) of 0.0659, mean absolute error of 0.0457, mean squared logarithmic error of 0.0037, R -squared of 0.8507, and explained variance ratio of 0.8512. These metrics indicate that the model provides satisfactory predictive accuracy, as they all represent values very close to 0 (with the exception of the R -squared metric in which case, a number closer to 1 indicates the model is well fitted); the lower the value, the better the accuracy of the model on its predictive features. The top eleven most influential features and their correlations with the dependent variable, standard deviation, and variance were also calculated. Features with higher importance are less likely to get the mpox vaccine.

This project was exempted as non-research by the DCoDPH Review Board, and therefore, IRB approval was not required.

Results

A total of 26,173 Jynneos vaccine doses were administered across North Carolina, including 2113 vaccine doses in Durham County. Overall, North Carolina had a more demographically equitable distribution of mpox vaccines compared to Durham County, with 27% of vaccines going to Black or African American individuals across North Carolina compared to only 19% of Durham County mpox vaccine

Table 1 Individuals who received the mpox vaccine at DCoDPH by race and ethnicity

Race and ethnicity	% of total (Durham County)	% of total (North Carolina)
White	73.1%	60.4%
Black or African American	18.7%	27.4%
Asian	6.9%	3.3%
American Indian or Alaskan Native	1.3%	0.6%
Hispanic or Latino	11.3%	10.0%

Table 2 Individuals who received the mpox vaccine at DCoDPH by sex and age

Age range	Female	Male
20–30	5.8%	27.3%
31–40	4.2%	34.4%
41–50	1.4%	17.6%
51–60	1.0%	12.0%
61–70	1.0%	9.0%
Over 70	0.2%	2.6%
Total	12.4%	87.6%

recipients (Table 1). In addition, 11% of vaccines in Durham County were given to Latino or Hispanic individuals compared to 10% across North Carolina [14]. At DCoDPH, sex differences in vaccine reception were evident with females being much less likely to be vaccinated than males against mpox (12% versus 88%, respectively). Most DCoDPH vaccine recipients were between the ages of 20 and 40 (Table 2).

When looking at mpox vaccine reception and SDOH, the variable most significantly associated with mpox vaccine reception was males living in a household with another male partner (Table 3). All other significant variables were a part of the SVI dataset. The SVI variables most associated with mpox vaccine reception were persons aged 25 or older with no high school diploma, noninstitutionalized individuals

who lacked health insurance, individuals 16 years or older who were unemployed, living 150% below the federal poverty level, and living in a household without a vehicle. In addition, identifying as Black or African American, Hispanic and Latino, or otherwise non-white was also associated with mpox vaccine reception. The remaining variables positively associated with mpox vaccine reception can be found in Table 3.

Discussion

The DCoDPH investigated the association between mpox vaccine reception, SDOH, and social vulnerability in Durham County, North Carolina. The variable that was most associated with mpox vaccine reception was being male and living with a male partner in 2022. These findings suggest that the DCoDPH was effective in its outreach efforts towards men who have sex with men (MSM) LGBTQI population in Durham County who were thought to be most at risk for mpox during the 2022 outbreak. By partnering with the LGBTQ Center of Durham, DCoDPH boosted its outreach programs and initiatives by being more visible in this community.

The DCoDPH partnered with Duke Health to administer mpox vaccinations at the Durham Pride event in September 2022 and partnered with the LGBTQ Center of Durham and North Carolina Central University (NCCU) to hold separate mpox vaccine events. In addition, the DCoDPH participated in numerous webinars and engaged in outreach via numerous social media modalities. Thus, community outreach events and coordination with trusted partners in the community proved to be an effective strategy for increasing mpox vaccine uptake.

Some additional variables that were positively associated with mpox vaccine reception included lacking a high school diploma, lacking health insurance, being unemployed, and

Table 3 Variables most associated with mpox vaccine reception

#	Feature	Importance
1	2022 male householder and male partner	8.34%
2	Persons age 25 + with no high school diploma	8.31%
3	Uninsured total civilian noninstitutionalized population	5.76%
4	Single-parent households with children under 18	5.37%
5	Housing units	5.31%
6	Civilian age 16 + unemployed	5.28%
7	Hispanic or Latino; Black or African American; other non-white races	3.92%
8	Percentage of persons below 150% of FPL	3.82%
9	Households with no vehicle available	3.42%
10	Housing in structures with 10 or more units estimate	3.40%
11	Percentage of persons age 5 + who speak English “less than well”	3.35%

FPL, federal poverty line

living below 150% of the federal poverty level. The fact that these variables were positively associated with mpox vaccine reception was surprising as these variables all represent underlying social vulnerability used to gauge the overall health of the community and its residents [20–22]. In prior studies, these variables have been associated with poor health outcomes including heart disease, diabetes, and obesity [20]. The fact that these variables were positively associated with mpox vaccine reception again likely reflects the community outreach done by the DCoDPH and other organizations in Durham County such as Duke Health during the height of the mpox outbreak.

Black or African American and Hispanic or Latino individuals face more barriers to vaccination than non-Hispanic white individuals due to gaps in dissemination of information, language barriers, racism, homophobia, xenophobia, stigma, discrimination, unemployment, lack of access to health care, and poverty [23]. Vaccine hesitancy is also closely associated with racial and health inequities among people of color [24–26]. Racial segregation and mistrust of the medical system from centuries of structural racism and mistreatment of people of color in scientific research contributed to COVID-19 vaccine hesitancy [24]. The DCoDPH used geocoding and census data during its COVID-19 vaccine outreach to target certain populations including people of color, areas with low educational attainment, and areas with high rates of unemployment. By utilizing these data sources, DCoDPH was able to identify areas of high inequity in Durham County and provide targeted outreach to combat these racial and health inequities seen with the COVID-19 vaccine administration. Achieving this success involved countless equity-based initiatives over 2 years from DCoDPH to ensure that this population was vaccinated [24] and strategies developed during the COVID-19 vaccine campaign were utilized during mpox vaccine outreach as well. Despite low overall mpox vaccination rates among the Black or African American population in Durham County, the DCoDPH did find that being Black or African American and Hispanic or Latino was positively associated with mpox vaccine reception, providing some evidence that the outreach to these populations was effective, even if vaccination rates overall were low due to some of the previously discussed barriers.

This study has several limitations. Firstly, while 2113 total Jynneos vaccine doses were administered in Durham County, the DCoDPH administered only 1373 of those doses (65.0%). The remaining vaccines were administered through partners at Duke University and NCCU, and we did not have access to these records. By only using data collected from DCoDPH, the estimates of variables associated with those receiving the mpox vaccine across Durham County may not be complete. Nevertheless, the DCoDPH is centrally located in Durham and serves a geographically and demographically

diverse community, so our findings are likely representative of the population in Durham County who received the mpox vaccine. In addition, this study relied on self-reported data. As in nearly all healthcare questionnaires, self-reporting bias can greatly influence the study's results. Sensitive questions such as sexual history, sexual orientation, sex identity, and HIV status can be considered intrusive and, as is the individual's prerogative, can be left blank or completed with an inaccurate response. Lastly, since this analysis involved only Durham County, North Carolina, our findings may not be generalizable to other settings in other geographic locations.

With documented cases of vaccine-breakthrough cases, the Centers for Disease Control and Prevention is recommending that local health departments stay vigilant [27], especially considering low overall vaccination rates across the USA (28), particularly among Black or African American individuals who have been disproportionately impacted by mpox. Continued equity-centered outreach to the LGBTQI and Black or African American populations is necessary to help prevent future mpox cases. Lastly, better understating of underlying factors associated with vaccine reception, including those related to SDOH and social vulnerability, will help outreach to historically marginalized populations who may be less inclined to receive vaccines for vaccine-preventable diseases.

Author Contribution SC and JDJ conceived and designed the study. SC, JDJ, and JPZ were involved in data collection. SC and JPZ analyzed the data. SC and JDJ wrote the initial draft. JPZ, ES, RJ, and MM provided critical comments. All authors read and approved the final manuscript.

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Declarations

Ethics Approval This project was exempted as non-research by the DCoDPH Review Board, and therefore, IRB approval was not required.

Conflict of Interest JDJ has received research funding from Astellas, F2G, and Pfizer—all unrelated to this work. All other authors declare no potential conflicts of interest.

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