Impact of NCDHHS COVID-19 Community Health Worker Program on Early COVID-19 Vaccination in North Carolina

Partners In Health (PIH) - United States

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Evaluation Summary

Background: To address COVID-19 vaccine equity challenges in early 2021, Community Health Workers (CHWs) were deployed in North Carolina to facilitate increased vaccination for historically marginalized populations. This study assessed the impact of CHW-supported vaccine clinics/events on COVID-19 vaccination rates during a period of limited vaccine supply.

Methods: Using state epidemiology and COVID-19 CHW Program data from February to June 2021, a generalized linear mixed model was employed to analyze the association between CHW-supported vaccination clinics and vaccination rates (partial, full, and total doses), considering time, race, ethnicity, and county-level variations. Additional models examined the interaction of CHW events and time, and race/ethnicity.

Results: In an unadjusted model, the presence of at least one vaccine clinic in a month was associated with a 66-75% increase in vaccination rates. In adjusted models, CHW events were associated with a 3-15% increase in vaccination rates. There was a slight (1-4%) month-to-month decrease in effect of CHW events on vaccination rates. CHW events were associated with an increase in vaccination rates by 34-62% for Black/African American, 19-25% for Asian/Pacific Islander, and 17-30% for "other" race populations. The effects of CHW events on Hispanic individuals did not demonstrate changes across vaccination outcomes. We observed similar results when analyzing the program across its full period of operation from February 2021 – December 2022.

Discussion: CHW efforts significantly contributed to increased COVID-19 vaccination rates, particularly for historically marginalized populations, during a time of limited supply and for the duration of the pandemic emphasizing the vital role of CHWs in addressing vaccine equity. The findings underscore the potential of CHWs to enhance vaccination access and utilization, providing valuable insights for public health planning and intervention strategies.

Background

As of January 31, 2021, there had been 757,000 confirmed cases of COVID-19 and nearly 10,000 COVID-19-related deaths documented in North Carolina [1]. Vaccination is crucial in reducing infection rates, severe illness, and mortality from COVID-19 [2]. Vaccines available in the United States from Moderna, Pfizer/BioNTech, and Johnson & Johnson were highly effective in preventing symptomatic and severe SARS-CoV-2 infection [3-5]. The United States began vaccination in mid-December 2020 to combat high levels of COVID-19, prioritizing healthcare workers and high-risk individuals [6-7]. There were disparities in the general acceptance of the COVID-19 vaccine among healthcare workers and historically marginalized populations (HMPs), primarily because of concerns about its safety and efficacy [7-8]. Consequently, differences in vaccine decision-making and unequal access may have influenced vaccination rates. Even beyond the declared end of the pandemic, ensuring equitable access and acceptance of COVID-19 vaccines among diverse populations remains a global health priority [8].

Community health workers (CHWs) are trusted members of their communities who link health and social care to the community to facilitate access to services and improve the quality and cultural competence of service delivery [9]. CHWs promote health knowledge and self-sufficiency by conducting outreach, education, counseling, support, and advocacy activities to build individual and community capacity. Numerous studies have shown that CHWs effectively promote vaccination uptake and improve immunization rates across different contexts. For example, a systematic review by Scott et al. showed that CHW-led interventions have effectively increased vaccination coverage, particularly among vulnerable populations [10]. Globally, CHW-led immunization programs positively influenced childhood vaccination coverage beyond the pandemic setting in low- and middle-income countries [11-13].

Like many other states, North Carolina implemented vaccination campaigns to achieve widespread immunization coverage. CHWs played a crucial role in the community-based COVID-19 response in North Carolina, especially among historically marginalized populations (HMPs). In September 2020, before the availability of COVID-19 vaccines, CHWs were deployed to half of the state's 100 counties based on COVID-19 rates to provide community-based COVID-19 education and facilitate social support for quarantine and isolation through a program funded by federal pandemic dollars and managed by the North Carolina Department of Health and Human Services (NCDHHS) Office of Rural Health (ORH) [14-15]. During COVID-19 vaccine rollout, CHWs were trusted messengers who provided community-based education and outreach and supported vaccine events and clinics [16].

Between January 2021 and December 2022, CHWs reached over 1.7 million people via outreach and COVID-19 education and directly coordinated over 60,000 COVID-19 immunizations [17-18]. This study intends to quantify the impact of CHWs on COVID-19 vaccination rates in North Carolina including total doses, partial vaccination (i.e., at least one vaccine dose), and full vaccination rates (i.e., completion of the recommended doses). To evaluate a time of decreased supply with increased demand where equity of access is a concern, we focused on the time period from February through June 2021 (in addition to an analysis of the full program duration), with the hypothesis that CHW involvement could positively impact vaccination rates among HMPs. Through this evaluation, we aim to provide empirical evidence regarding the efficacy of CHW-led efforts in promoting COVID-19 vaccination uptake.

Methods

Program Design

In August 2020, NCDHHS ORH selected CHW vendors (organizations employing CHWs) to deploy CHWs across 50 counties based on the severe impact of the first wave of COVID-19 in the state and the underlying vulnerability of the population in that county. From September 2020 through January 2021, the primary role of CHWs was to support safe quarantine and isolation for vulnerable populations through community-based outreach and messaging, as well as care resource coordination. The COVID-19 CHW Program was paired with a COVID-19 Support Services Program to finance and directly provide social supports to HMPs [16].

From February through June 2021, North Carolina rolled out the COVID-19 vaccine among subsequent tiers of priority populations with demand that significantly exceeded supply. To promote equity during this period, NCDHHS set aside a weekly vaccine equity allocation reserved for HMPs and relied on local networks, which included CHWs, to identify eligible individuals to receive those doses [17-18]. CHWs were trained and deployed in outreach activities to promote equity access and utilization of vaccination by hosting educational events and community-based vaccine clinics/events. By this time, the number of counties served by CHWs ("CHW prioritized" counties) had increased to 55/100. CHWs in the program received monthly COVID-19 vaccine education, available in English and Spanish, to provide an educational foundation and regular updates and assistance to address common myths and misinformation. CHW vaccine efforts also included scheduling individuals for vaccine appointments, facilitating transportation to/from appointments, and supporting second doses (appointments, reminders, transportation, etc.) [18]. While community canvassing increased steadily during this period, the vaccine event strategy evolved. In February and March 2021, large-scale ("mass") vaccine events were more commonly supported by CHWs (e.g., Greensboro National Guard COVID-19 Community Vaccination Center), transitioning to Local Health Departments and/or NCDHHS vaccine vendor events from April to June 2021. Community-based or mobile vaccination clinics started in late May 2021. Vaccine equity efforts by CHWs continued in July 2021 and beyond, with the expansion to all 100 counties in the fall of 2021 [19].

Assumptions and Definitions

From February through June 2021, vaccine supply was limited compared to July 2021 and beyond. We defined the COVID-19 partially vaccinated rate as the proportion of individuals who received at least one dose of an approved COVID-19 vaccine and the fully vaccinated rate as the proportion of individuals who received two doses of Pfizer/BioNTech and Moderna vaccines or one dose of the Johnson & Johnson vaccine as per the CDC definition during the study period [20]. Due to the absence of booster dose recommendations during this study's primary period of focus, we did not consider (i.e., excluded) booster doses.

Data Sources

The Epidemiology Section of the NCDHHS Division of Public Health provided county-level data on COVID-19 vaccination rates throughout CHW involvement in vaccination efforts (February 2021 – December 2022). The data contains five measures for each county, including demographic variables. Monthly vaccine outreach and education data and CHW-supported vaccine clinics were obtained from the NCDHHS ORH CHW Data Dashboard, which collated data on the COVID-19 CHW Program from

contracted vendors. Weekly cumulative COVID-19 cases were obtained from the Johns Hopkins Coronavirus Resource Center Dashboard [1].

Outcome Variables

Three outcome measures were utilized to assess the impact of CHWs on COVID-19 vaccination efforts. The primary outcome was the cumulative full vaccination rate per 10,000 population. Secondary outcomes included the cumulative partial vaccination rate and the cumulative doses administered rate per 10,000 population.

Explanatory Variables

Two explanatory variables were considered. The first variable was binary, indicating whether a county had hosted CHW vaccination clinic events during a given month. The second variable was time, expressed continuously by month. These variables were selected to examine the influence of CHW intervention and temporal factors on vaccination rates across different counties.

Additional Covariates

To understand the impact of race and ethnicity on vaccination rates, these were included as categorical variables in adjusted models. To prevent collinearity, we intentionally excluded variables that showed a high correlation with the presence of CHW-supported vaccination clinics, such as CHW outreach and education efforts.

Models

We used a multivariable generalized linear mixed model (GLMM) to model cumulative partial, full, and administered vaccination rates (with five measurements taken per county over the study period) for all 100 counties in North Carolina from February to June 2021. We accounted for variation between counties by including fixed effects for each county, which were explained by covariates in the model, such as CHW-supported vaccination clinics. Additionally, we included a random effect for each county to account for variance within a county. In separate models, we included an interaction term to examine the effects between time and vaccination clinics on vaccination rates, and whether the relationship between CHW events and vaccination rates differs among racial and ethnic groups. We then calculated β, where Y represents the exponential (log) partial/full vaccination coverage rate. We also ran these models for the full duration of CHW efforts during the program (February 2021 – December 2022).

Statistical Analysis

We initially assessed the data distribution using a histogram, Q-Q plot, and the Shapiro-Wilk test. Due to identified skewness in the outcome variables, we applied a logarithmic transformation to stabilize variance and normalize the data. The data were analyzed using the R programming language [21]. Data formatting was done using three packages, gt, gtsummary, and dplyr [22-24]. The creation of scatter, correlation, and other plots involved using two packages, ggplot2 and tidyverse [25-26]. We employed the lme4 package to implement fixed and random effects within a GLMM [27]. We utilized Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Bayes Factor to compare the efficacy of different models. These metrics helped identify the model that best fit the data while adequately balancing complexity and explanatory power.

Results

Demographics, COVID-19 cases, and vaccination percentages of CHW prioritized and non-prioritized counties

Baseline characteristics of CHW prioritized (n=55) and non-prioritized (n=45) counties are found in Table 1. CHW prioritized counties had higher median Social Vulnerability Index (SVI) values (0.6 [IQR 0.4-0.8]) vs 0.4 [IQR 0.2-0.6] and a larger proportion of Black/African American (23% [IQR 12.9-34.4] vs 4.9% [IQR 1.7-20.1]) and Hispanic (10.1% [IQR 7.5-13.4] vs 5.4% [IQR 4.2-7.2]) populations as compared to non-prioritized counties. Non-prioritized counties were more rural (84%) as compared to prioritized counties (58%) and had a higher proportion of White race (81.6% [IQR 70.5-86.5] vs 58.3% [IQR 47.2-67.5]).

At the onset of CHW deployment to support vaccination efforts in February 2021, prioritized counties had slightly higher initial COVID-19 case rates (8%) compared to non-prioritized counties (7%). In February, partial and fully vaccinated rates across the state were 12% and 4%, respectively. CHW prioritized counties had slightly lower median partial (11%) and fully (3%) vaccinated rates compared to the partial (12%) and full (4%) in non-prioritized counties. By the end of June, partial and fully vaccinated rates increased substantially across the state to 40.5% and 38%, respectively. The median partial and full vaccination rate in counties prioritized by CHWs were 41% and 39%, as compared to 39% and 37% in non-prioritized counties (Table 1).

CHW-supported vaccination efforts

CHWs facilitated 2,310 vaccination clinics and events from February through June 2021, with 99% of these clinics occurring in counties prioritized by CHWs. The distribution of vaccine education events closely mirrored the pattern of vaccination clinics, exemplifying a concerted effort to deliver both education and vaccination services. Most vaccination clinics were concentrated in prioritized counties with a rapid increase from March to April that was maintained through June (Supplemental Table 1).

CHW impact on COVID-19 vaccination rates

In the unadjusted model, CHW events were found to increase COVID-19 cumulative vaccination rates. From February to June 2021, the presence of at least one CHW event in a county was associated with an increase in cumulative partially vaccinated rates by a factor of about 1.75 (75%, 95 CI: 1.61 - 1.90) (Table 2). For the same period, cumulative rates for fully vaccinated and administered vaccines rose by factors of 1.66 (66%, 95 CI: 1.52 - 1.81) and 1.67 (67%, 95 CI: 1.50 – 1.85), respectively (Tables 3-4). Extending the analysis from February 2021 to December 2022, this positive trend persisted across all vaccination outcomes (Supplemental Tables 2-4).

In multivariable models adjusted for time, race, and ethnicity from February – June 2021, CHW events contributed to a 3% increase in partially vaccinated rates (95% CI: 0.96-1.11), 6% increase in fully vaccinated rates (95% CI: 0.99-1.14), and 15% increase in administered vaccination rates (95% CI: 1.27-1.40, Tables 2-4). Through December 2022, these increases were more pronounced: 33% for partial (95% CI: 1.28-1.39), 35% for full (95% CI: 1.29-1.40), and 34% for administered (95% CI: 1.27-1.40) vaccination rates (Supplemental Tables 2-4).

Across adjusted models, time was a significant positive predictor of vaccination rates. American Indian/Alaskan Native, Asian/Pacific Islander, Black/African American, other race, and undisclosed race groups had lower partial, full, and administered vaccination rated compared to the White race reference

group across all adjusted models. Hispanic and undisclosed ethnicity groups also had lower partial, full, and administered vaccination rates compared to the non-Hispanic reference group (Tables 2-4).

Temporal trends in the efficacy of CHW events on vaccination rates

From February to June 2021, there was a slight month-to-month decrease in effect of CHW events on partial (0.96, 95% CI: 0.92-0.99, full (0.99, 95% CI: 0.05-1.03), and administered (0.97, 95% CI: 0.02-1.02) vaccination rates. This trend was similar in analysis through December 2022 (Supplemental Tables 2-4).

Variability of CHW event impact on vaccination rates across race and ethnicity

The impact of CHW events on cumulative vaccination rates exhibited variability across different racial and ethnic groups when compared to White and non-Hispanic individuals. For Black/African American race, the presence of CHW events were associated with increased vaccination rates: 43% for partial (95% CI: 1.25-1.64), 34% for full (95% CI: 1.17-1.53), and 62% for administered (95% CI: 1.36 – 1.93) vaccination rates. Asian/Pacific Islander race also experienced notable improvements, with increases of 23% for partial (95% CI: 1.05-1.43), 19% for full (95% CI: 1.02-1.38), and 23% for administered vaccination rates (95% CI: 1.01-1.49). Increases were also observed across vaccination outcomes for "other" race. In contrast, American Indians/Alaskan Natives and individuals with race undisclosed did not show significant changes in vaccination rates. The effects of CHW events on Hispanic individuals did not demonstrate changes across vaccination outcomes. Individuals with undisclosed ethnicity experienced a negative association with CHW events: 16% partial (95% CI: 0.75-0.95), 8% full (95% CI: 0.81-1.03), 26% administered (95% CI: 0.64-0.85) vaccination rates (Tables 2-4).

These changes persisted across the duration of the program through December 2022. For Black/African Americans and Asians/Pacific Islanders, the increases in vaccination rates remained statistically significant across all categories: partial, full, and administered vaccinations during the extended period through December 2022 (Supplemental tables 1-3).

Discussion

The COVID-19 pandemic had a disproportionate impact on historically marginalized populations in North Carolina. The deliberate deployment of CHWs in counties with higher cumulative COVID-19 rates and SVI (i.e., more vulnerable), where a significant proportion of COVID-19 vaccination events were conducted, demonstrated a conscious effort to address the needs of HMPs. There was a clear association between CHW-supported vaccine clinics and events and vaccination rates. In adjusted regression models accounting for time and additional covariates, there was an association between the presence of at least one CHW vaccine clinic in a country and vaccination rates. Additionally, there was an association between CHW events and increases in vaccination rates among Black/African American, Asian/Pacific Islander, and "other" races. The results demonstrate that CHWs were crucial in enhancing vaccine accessibility and equitable distribution among socially vulnerable populations during a time of limited supply. Furthermore, the augmented impact of CHW events between February 2021 and December 2022 demonstrates that CHWs contributed to the sustained vaccine response throughout the pandemic.

CHWs were a cornerstone of the community-based vaccine equity response in North Carolina. Disparities in vaccination rates among Black and Hispanic individuals in the early vaccine response were previously described [16], and these results provide one potential mechanism for increasing vaccination

among Black/African American, Asian/Pacific Islander, and "other" races during the February – June 2021 period and through the end of the COVID-19 CHW Program in December 2022. As trusted members coming from and with lived experience shared with the communities they serve, CHWs are positioned to enhance access, build trust, and dispel misinformation related to vaccination [16-17]. While CHW-supported vaccine events were utilized as the outcome variable for this analysis, they are intertwined with other CHW activities including education/outreach or reducing barriers to vaccination (e.g., coordinating transportation, providing second dose reminders, etc.), which should be considered jointly when explaining the observed results.

The neutral response observed in the multivariable regression related to vaccination among individuals identifying as Hispanic ethnicity is likely multifaceted. While one could hypothesize that the results of this analysis could stem from a limitation in reaching Hispanic populations or breaking down barriers to vaccination, it could also have resulted from limitations of the analysis itself. A general limitation of this study is the use of whether a CHW clinic occurred in a county on a given month as a binary variable rather than treating CHW clinics/events as a continuous variable. This outcome variable transformation was necessary to assess race and ethnicity together in the adjusted model because the CHW event and vaccine, race, and ethnicity datasets were separate and linked by county and time rather than individual or event. Notably, while vaccination rates among Hispanic populations lagged for the early part of 2021, rates surpassed non-Hispanic populations by the end of that year [16]. It is also unclear why a negative interaction existed between whether a CHW clinic occurred and undisclosed ethnicity. Exploration of the composition of the group that is more likely not to disclose ethnicity may shed light on this finding.

North Carolina implemented a rapid statewide COVID-19 vaccine strategy focused on vaccinating people as quickly and equitably as possible [19, 28-29]. It is unsurprising that time slightly attenuated the impact of CHW events on vaccination rates. The last mile of vaccine uptake across the population is more challenging. The COVID-19 CHW Program was one of many initiatives and innovations during the pandemic, with a multi-faceted vaccine response that grew and evolved to reach more of the state. NCDHHS worked to build equity into every aspect of its COVID-19 prevention and response across three key areas: trust-based partnerships with historically marginalized communities, ensuring equity in vaccine allocation and delivery operations, and using data to promote accountability and drive decisions [19]. Data that identified existing disparities and this equity-driven policy drove additional NCDHHS investment in vaccine equity efforts beyond June 2021. These included the expansion of the COVID-19 CHW Program statewide, the launch of the Healthier Together initiative to strengthen trust-based community partnerships, and the engagement of healthcare providers for equitable vaccine distribution [19]. Synergy across these programs likely contributed to the narrowing of the equity gap between Black/African American and White as well as Hispanic and non-Hispanic populations across the state [16].

Many studies have reported that vaccination efforts supported by CHWs have increased vaccine uptake rates globally. Our findings indicate that CHWs can help improve access and distribution of COVID-19 vaccines, with a key impact of closing the equity gap among HMPs across North Carolina. Additional studies demonstrating the impact of CHWs across other health and social care domains provide a breadth of evidence-based roles for CHWs during pandemic emergency response that add to existing CHW Core Consensus (C3) Project roles [29-30]. Integrating CHWs across public health, health, and

social care systems could improve vaccine equity and expand access to underserved communities while providing additional services to promote whole person health.

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Figures/Tables

Table 1. Comparison of race, ethnicity, socioeconomic, COVID-19 case, and COVID-19 vaccination data in CHW prioritized (n=45), non-prioritized (n=55), and all (n=100) counties. Data is presented as median with interquartile range (IQR), unless otherwise noted. County-level demographics were obtained from the U.S. Census Bureau American Community Survey 5-Year Estimates (2020). COVID-19 case and vaccination rates were obtained from the Johns Hopkins Coronavirus Resource Center Dashboard.

Variables	**Prioritized Counties**, n = 55	**Non-prioritized Counties**, n =45	**North Carolina**, n = 100
Race[1]			
White	58.30 (47.20, 67.50)	81.60 (70.50, 86.50)	65.40 (52.98, 81.13)
Black/African American	23.00 (12.85, 34.35)	4.90 (1.70, 20.10)	16.80 (4.88, 29.93)
Multiracial	3.70 (2.85, 3.95)	3.70 (3.30, 4.00)	3.70 (3.00, 4.00)
Asian/Pacific Islander	1.00 (0.50, 1.70)	0.50 (0.30, 0.90)	0.70 (0.40, 1.33)
American Indian	0.30 (0.25, 0.50)	0.30 (0.30, 0.50)	0.30 (0.28, 0.50)
All Other Races	0.40 (0.30, 0.50)	0.30 (0.30, 0.40)	0.40 (0.30, 0.50)
Ethnicity[1]			
Non-Hispanic	90.00 (86.50, 92.50)	95.00 (93.00, 96.00)	92.50 (89.00, 95.00)
Hispanic	10.00 (7.50, 13.50)	5.00 (4.00, 7.00)	7.50 (5.00, 11.00)
Socioeconomics			
Location (by county)[2]			
Rural	32.00 (58.18)	38.00 (84.44)	70.00 (70.00)
Urban	23.00 (41.82)	7.00 (15.56)	30.00 (30.00)
Social Vulnerability Index[1]	0.63 (0.39, 0.84)	0.35 (0.15, 0.58)	0.50 (0.25, 0.75)
Cumulative COVID-19 Case Rates[3]			
February 2021	8.00 (7.00, 9.00)	7.00 (6.00, 9.00)	8.00 (6.00, 9.00)
June 2021	10.00 (9.50, 12.00)	9.00 (8.00, 11.00)	10.00 (9.00, 12.00)
COVID-19 Cumulative Partial, Full, and Total Vaccinations[3]			
Partial (February 2021)	11.00 (9.00, 13.00)	12.00 (10.00, 15.00)	12.00 (9.00, 13.25)
Partial (June 2021)	41.00 (37.00, 45.50)	39.00 (37.00, 46.00)	40.50 (37.00, 46.00)
Full (February 2021)	3.00 (3.00, 5.00)	4.00 (3.00, 5.00)	4.00 (3.00, 5.00)
Full (June 2021)	39.00 (34.50, 41.50)	37.00 (35.00, 44.00)	38.00 (35.00, 43.00)
Total (April 2021)	47.00 (39.50, 51.00)	49.00 (44.00, 57.00)	48.00 (43.00, 53.25)
Total (June 2021)	63.00 (55.00, 70.00)	65.00 (58.00, 72.00)	63.00 (56.75, 71.00)

[1] Data Source: U.S. Census Bureau. American Community Survey, ACS 5-Year Estimates, 2020

[2] Frequency (%)

[3] Data Source: Johns Hopkins Coronavirus Resource Center Dashboard

Table 2. Effect of CHW events on partial COVID-19 vaccination rates February – June 2021. Multivariable generalized linear mixed models on partial vaccination rates including random (county) and fixed effects: unadjusted model – CHW events only; adjusted model – CHW events, time, race, ethnicity; time interaction – CHW event, time, CHW event x time; race/ethnicity interaction – CHW event, race, ethnicity, CHW event x race, CHW event x ethnicity. Estimates β calculated from Y exponential (log) vaccination rate with 95% Confidence Interval. Data sources include North Carolina Department of Health and Human Services Division of Public Health Epidemiology Section and the Office of Rural Health.

	Unadjusted Model		**Adjusted Model**		**Time Interaction**		**Race/Ethnicity Interaction**	
Covariate	*Estimates*	*CI*	*Estimates*	*CI*	*Estimates*	*CI*	*Estimates*	*CI*
(Intercept)	3.54 ***	3.19 – 3.93	10.87 ***	9.99 – 11.82	1.82 ***	1.65 – 2.02	21.10 ***	18.96 – 23.48
CHW Event [Yes]	1.75 ***	1.61 – 1.90	1.03	0.96 – 1.11	1.05	0.93 – 1.20	1.62 ***	1.43 – 1.83
time [month]			1.34 ***	1.32 – 1.36	1.40 ***	1.36 – 1.43		
race [American Indian or Alaskan Native]			0.13 ***	0.12 – 0.14			0.11 ***	0.10 – 0.13
race [Asian or Pacific Islander]			0.22 ***	0.21 – 0.24			0.19 ***	0.17 – 0.21
race [Black or African-American]			0.43 ***	0.41 – 0.46			0.36 ***	0.32 – 0.39
race [Other]			0.41 ***	0.39 – 0.43			0.35 ***	0.32 – 0.38
Race [Undisclosed]			0.21 ***	0.20 – 0.23			0.19 ***	0.17 – 0.22
ethnicity [Hispanic]			0.36 ***	0.34 – 0.38			0.37 ***	0.34 – 0.40
ethnicity [Undisclosed]			0.23 ***	0.22 – 0.24			0.24 ***	0.22 – 0.26
CHW Event [Yes] × time					0.96 *	0.92 – 0.99		

CHW Event [Yes] × race [American Indian or Alaskan Native]							1.16	0.99 – 1.36
CHW Event [Yes] × race [Asian or Pacific Islander]							1.23 **	1.05 – 1.43
CHW Event [Yes] × race [Black or African-American]							1.43 ***	1.25 – 1.64
CHW Event [Yes] × race [Other]							1.30 ***	1.14 – 1.48
CHW Event [Yes] × race [Undisclosed]							1.09	0.93 – 1.26
CHW Event [Yes] × ethnicity [Hispanic]							0.95	0.85 – 1.05
CHW Event [Yes] × ethnicity [Undisclosed]							0.84 **	0.75 – 0.95

Random Effects

σ^2	1.18	0.51	1.05	0.63
τ_{00}	0.22 $_{County}$	0.07 $_{County}$	0.12 $_{County}$	0.14 $_{County}$
ICC	0.16	0.13	0.10	0.18
N	99 $_{County}$	99 $_{County}$	99 $_{County}$	99 $_{County}$
Observations	7674	5131	7674	5131
Marginal R^2 / Conditional R^2	0.052 / 0.202	0.620 / 0.668	0.128 / 0.218	0.531 / 0.616

*p<0.05 ** p<0.01 *** p<0.001*

Table 3. Effect of CHW events on full COVID-19 vaccination rates February – June 2021. Multivariable generalized linear mixed models on full vaccination rates including random (county) and fixed effects: unadjusted model – CHW events only; adjusted model – CHW events, time, race, ethnicity; time interaction – CHW event, time, CHW event x time; race/ethnicity interaction – CHW event, race, ethnicity, CHW event x race, CHW event x ethnicity. Estimates β calculated from Y exponential (log) vaccination rate with 95% Confidence Interval. Data sources include North Carolina Department of Health and Human Services Division of Public Health Epidemiology Section and the Office of Rural Health.

	Unadjusted Model		**Adjusted Model**		**Time Interaction**		**Race/Ethnicity Interaction**	
Covariates	*Estimates*	*CI*	*Estimates*	*CI*	*Estimates*	*CI*	*Estimates*	*CI*
(Intercept)	3.49 ***	3.13 – 3.90	9.52 ***	8.72 – 10.39	1.87 ***	1.67 – 2.09	19.38 ***	17.27 – 21.76
CHW Event [Yes]	1.66 ***	1.52 – 1.81	1.06	0.99 – 1.14	0.98	0.85 – 1.13	1.83 ***	1.61 – 2.06
time [month]			1.38 ***	1.36 – 1.40	1.33 ***	1.29 – 1.37		
race [American Indian or Alaskan Native]			0.13 ***	0.12 – 0.14			0.12 ***	0.11 – 0.14
race [Asian or Pacific Islander]			0.21 ***	0.19 – 0.22			0.19 ***	0.17 – 0.21
race [Black or African-American]			0.44 ***	0.41 – 0.46			0.38 ***	0.35 – 0.42
race [Other]			0.43 ***	0.40 – 0.45			0.39 ***	0.36 – 0.43
race [Undisclosed]			0.21 ***	0.19 – 0.22			0.23 ***	0.20 – 0.25
ethnicity [Hispanic]			0.31 ***	0.29 – 0.32			0.31 ***	0.29 – 0.34
ethnicity [Undisclosed]			0.21 ***	0.20 – 0.22			0.21 ***	0.20 – 0.23
CHW Event [Yes] × time					0.99	0.95 – 1.03		
CHW Event [Yes] × race							1.16	0.98 – 1.36

[American Indian or Alaskan Native]								
CHW Event [Yes] × race [Asian or Pacific Islander]							1.19 *	1.02 – 1.38
CHWEvent [Yes] × race [Black or African-American]							1.34 ***	1.17 – 1.53
CHW Event [Yes] × race [Other]							1.17 *	1.03 – 1.34
CHW Event [Yes] × race [Undisclosed]							0.93	0.80 – 1.08
CHW Event [Yes] × ethnicity [Hispanic]							1.02	0.92 – 1.13
CHW Event [Yes] × ethnicity [Undisclosed]							0.92	0.81 – 1.03

Random Effects

σ^2	1.22	0.48	1.11	0.63
τ_{00}	0.24 $_{County}$	0.10 $_{County}$	0.15 $_{County}$	0.19 $_{County}$
ICC	0.17	0.17	0.12	0.23
N	99 $_{County}$	99 $_{County}$	99 $_{County}$	99 $_{County}$
Observations	7492	5180	7492	5180
Marginal R^2 / Conditional R^2	0.042 / 0.201	0.634 / 0.695	0.096 / 0.201	0.522 / 0.631

*p<0.05 ** p<0.01 *** p<0.001*

Table 4. Effect of CHW events on total administered COVID-19 vaccination rates February – June 2021. Multivariable generalized linear mixed models on total administered vaccination rates including random (county) and fixed effects: unadjusted model – CHW events only; adjusted model – CHW events, time, race, ethnicity; time interaction – CHW event, time, CHW event x time; race/ethnicity interaction – CHW event, race, ethnicity, CHW event x race, CHW event x ethnicity. Estimates β calculated from Y exponential (log) vaccination rate with 95% Confidence Interval. Data sources include North Carolina Department of Health and Human Services Division of Public Health Epidemiology Section and the Office of Rural Health.

	Unadjusted Model		**Adjusted Model**		**Time Interaction**		**Race/Ethnicity Interaction**	
Covariate	*Estimates*	*CI*	*Estimates*	*CI*	*Estimates*	*CI*	*Estimates*	*CI*
(Intercept)	5.41 ***	4.91 – 5.96	45.54 ***	40.89 – 50.74	2.53 ***	2.26 – 2.84	93.53 ***	82.27 – 106.32
CHW Event [Yes]	1.67 ***	1.50 – 1.85	1.15 **	1.05 – 1.26	1.04	0.87 – 1.24	1.93 ***	1.65 – 2.26
time [month]			1.38 ***	1.35 – 1.41	1.41 ***	1.36 – 1.46		
race [American Indian or Alaskan Native]			0.05 ***	0.04 – 0.05			0.04 ***	0.04 – 0.05
race [Asian or Pacific Islander]			0.09 ***	0.08 – 0.10			0.08 ***	0.07 – 0.09
race [Black or African-American]			0.25 ***	0.23 – 0.27			0.19 ***	0.17 – 0.22
race [Other]			0.24 ***	0.22 – 0.26			0.21 ***	0.18 – 0.23
race [Undisclosed]			0.08 ***	0.08 – 0.09			0.09 ***	0.08 – 0.10
ethnicity [Hispanic]			0.18 ***	0.17 – 0.19			0.18 ***	0.17 – 0.20
ethnicity [Undisclosed]			0.10 ***	0.09 – 0.11			0.11 ***	0.10 – 0.12

CHW Event [Yes] × time					0.97	0.92 – 1.02		
CHW Event [Yes] × race [American Indian or Alaskan Native]							1.08	0.88 – 1.32
CHW Event [Yes] × race [Asian or Pacific Islander]							1.23 *	1.01 – 1.49
CHW Event [Yes] × race [Black or African-American]							1.62 ***	1.36 – 1.93
CHW Event [Yes] × race [Other]							1.29 **	1.08 – 1.53
CHW Event [Yes] × race [Undisclosed]							0.93	0.77 – 1.12
CHW Event [Yes] × ethnicity [Hispanic]							0.92	0.81 – 1.05
CHW Event [Yes] × ethnicity [Undisclosed]							0.74 ***	0.64 – 0.85

Random Effects

σ^2	2.52	1.04	2.36	1.18
τ_{00}	0.14 $_{County}$	0.10 $_{County}$	0.07 $_{County}$	0.16 $_{County}$
ICC	0.05	0.09	0.03	0.12
N	99 $_{County}$	99 $_{County}$	99 $_{County}$	99 $_{County}$

Observations	8812	5932	8812	5932
Marginal R^2 / Conditional R^2	0.024 / 0.077	0.649 / 0.681	0.075 / 0.102	0.600 / 0.648

*p<0.05 ** p<0.01 *** p<0.001*

Supplemental Materials

Supplemental Table 1. **Distribution of COVID-19 CHW Program vaccination events in North Carolina from February to June 2021.** Clinics presented by CHW prioritized (n=55), non-prioritized (n=45), and all (n=100) counties. Data source North Carolina Department of Health and Human Services Office of Rural Health.

Month	Prioritized Counties	Non-prioritized Counties	North Carolina
February	37	0	37
March	132	1	133
April	796	7	803
May	719	12	731
June	603	3	606
Total	2,287	23	2,310

Supplemental Table 2. Effect of CHW events on partial COVID-19 vaccination rates February 2021 – December 2022. Multivariable generalized linear mixed models on partial vaccination rates including random (county) and fixed effects: unadjusted model – CHW events only; adjusted model – CHW events, time, race, ethnicity; time interaction – CHW event, time, CHW event x time; race/ethnicity interaction – CHW event, race, ethnicity, CHW event x race, CHW event x ethnicity. Estimates β calculated from Y exponential (log) vaccination rate with 95% Confidence Interval. Data sources include North Carolina Department of Health and Human Services Division of Public Health Epidemiology Section and the Office of Rural Health.

	Unadjusted Model		**Adjusted Model**		**Time Interaction**		**Race/Ethnicity Interaction**	
Covariates	*Estimates*	*CI*	*Estimates*	*CI*	*Estimates*	*CI*	*Estimates*	*CI*
(Intercept)	5.29 ***	4.70 – 5.95	23.34 ***	21.60 – 25.23	2.95 ***	2.64 – 3.29	39.76 ***	36.16 – 43.73
CHW Event [Yes]	2.72 ***	2.59 – 2.87	1.33 ***	1.28 – 1.39	1.63 ***	1.53 – 1.75	1.95 ***	1.81 – 2.10
time [month]			1.08 ***	1.07 – 1.08	1.14 ***	1.13 – 1.14		
race [American Indian or Alaskan Native]			0.10 ***	0.10 – 0.11			0.07 ***	0.06 – 0.08
race [Asian or Pacific Islander]			0.18 ***	0.17 – 0.19			0.13 ***	0.12 – 0.15

race [Black or African-American]			0.44 ***	0.42 – 0.46			0.31 ***	0.29 – 0.34
race [Other]			0.40 ***	0.38 – 0.41			0.31 ***	0.29 – 0.34
race [Undisclosed]			0.20 ***	0.19 – 0.21			0.16 ***	0.15 – 0.18
ethnicity [Hispanic]			0.34 ***	0.33 – 0.35			0.32 ***	0.30 – 0.35
ethnicity [Undisclosed]			0.17 ***	0.17 – 0.18			0.18 ***	0.17 – 0.20
CHW Event [Yes] × time					0.97 ***	0.97 – 0.98		
CHW Event [Yes] × race [American Indian or Alaskan Native]							1.13	0.99 – 1.28
CHW Event [Yes] × race [Asian or Pacific Islander]							1.17 **	1.04 – 1.31
CHW Event [Yes] × race [Black or African-American]							1.46 ***	1.33 – 1.61
CHW Event [Yes] × race [Other]							1.23 ***	1.12 – 1.35
CHW Event [Yes] × race [Undisclosed]							1.14 *	1.01 – 1.27
CHW Event [Yes] × ethnicity [Hispanic]							0.95	0.88 – 1.02
CHW Event [Yes] × ethnicity [Undisclosed]							0.79 ***	0.72 – 0.87

Random Effects

σ^2	1.72	0.66	1.36	0.82
τ_{00}	0.32 $_{\text{County}}$	0.11 $_{\text{County}}$	0.26 $_{\text{County}}$	0.13 $_{\text{County}}$

ICC	0.16	0.15	0.16	0.14
N	99 County	99 County	99 County	99 County
Observations	22262	15515	22262	15515
Marginal R^2 / Conditional R^2	0.089 / 0.230	0.649 / 0.700	0.238 / 0.361	0.577 0.636

*p<0.05 ** p<0.01 *** p<0.001*

Supplemental Table 3. Effect of CHW events on full COVID-19 vaccination rates February 2021 – December 2022. Multivariable generalized linear mixed models on full vaccination rates including random (county) and fixed effects: unadjusted model – CHW events only; adjusted model – CHW events, time, race, ethnicity; time interaction – CHW event, time, CHW event x time; race/ethnicity interaction – CHW event, race, ethnicity, CHW event x race, CHW event x ethnicity. Estimates β calculated from Y exponential (log) vaccination rate with 95% Confidence Interval. Data sources include North Carolina Department of Health and Human Services Division of Public Health Epidemiology Section and the Office of Rural Health.

	Unadjusted Model		**Adjusted Model**		**Time Interaction**		**Race/Ethnicity Interaction**	
Covariates	*Estimates*	*CI*	*Estimates*	*CI*	*Estimates*	*CI*	*Estimates*	*CI*
(Intercept)	5.35 ***	4.75 – 6.04	22.56 ***	20.80 – 24.47	2.82 ***	2.51 – 3.16	40.33 ***	36.53 – 44.54
CHW Event [Yes]	2.61 ***	2.47 – 2.75	1.35 ***	1.29 – 1.40	1.53 ***	1.43 – 1.65	2.04 ***	1.89 – 2.20
time [month]			1.08 ***	1.08 – 1.09	1.14 ***	1.13 – 1.15		
race [American Indian or Alaskan Native]			0.10 ***	0.09 – 0.10			0.07 ***	0.06 – 0.08
race [Asian or Pacific Islander]			0.18 ***	0.17 – 0.19			0.13 ***	0.12 – 0.15
race [Black or African-American]			0.43 ***	0.42 – 0.45			0.32 ***	0.29 – 0.35
race [Other]			0.41 ***	0.40 – 0.43			0.33 ***	0.30 – 0.36
race [Undisclosed]			0.20 ***	0.19 – 0.21			0.18 ***	0.16 – 0.20
ethnicity [Hispanic]			0.30 ***	0.29 – 0.31			0.28 ***	0.27 – 0.30

ethnicity [Undisclosed]			0.16 ***	0.15 – 0.17			0.16 ***	0.15 – 0.17
CHW Event [Yes] × time					0.98 ***	0.97 – 0.98		
CHW Event [Yes] × race [American Indian or Alaskan Native]							1.07	0.94 – 1.22
CHW Event [Yes] × race [Asian or Pacific Islander]							1.14 *	1.01 – 1.28
CHW Event [Yes] × race [Black or African-American]							1.38 ***	1.25 – 1.52
CHW Event [Yes] × race [Other]							1.20 ***	1.09 – 1.32
CHW Event [Yes] × race [Undisclosed]							1.00	0.89 – 1.13
CHW Event [Yes] × ethnicity [Hispanic]							0.98	0.91 – 1.06
CHW Event [Yes] × ethnicity [Undisclosed]							0.86 **	0.78 – 0.94

Random Effects

σ^2	1.79	0.65	1.41	0.84
τ_{00}	0.33 $_{County}$	0.13 $_{County}$	0.27 $_{County}$	0.15 $_{County}$
ICC	0.16	0.16	0.16	0.15
N	99 $_{County}$	99 $_{County}$	99 $_{County}$	99 $_{County}$
Observations	22308	15683	22308	15683
Marginal R^2 / Conditional R^2	0.077 / 0.220	0.662 / 0.717	0.235 / 0.359	0.578 / 0.643

*p<0.05 ** p<0.01 *** p<0.001*

Supplemental Table 4. Effect of CHW events on total administered COVID-19 vaccination rates February 2021 – December 2022. Multivariable generalized linear mixed models on total administered vaccination rates including random (county) and fixed effects: unadjusted model – CHW events only; adjusted model – CHW events, time, race, ethnicity; time interaction – CHW event, time, CHW event x time; race/ethnicity interaction – CHW event, race, ethnicity, CHW event x race, CHW event x ethnicity. Estimates β calculated from Y exponential (log) vaccination rate with 95% Confidence Interval. Data sources include North Carolina Department of Health and Human Services Division of Public Health Epidemiology Section and the Office of Rural Health.

	Unadjusted Model		**Adjusted Model**		**Time Interaction**		**Race/Ethnicity Interaction**	
Covariates	*Estimates*	*CI*	*Estimates*	*CI*	*Estimates*	*CI*	*Estimates*	*CI*
(Intercept)	8.60 ***	7.68 – 9.63	98.21 ***	89.93 – 107.25	4.16 ***	3.73 – 4.63	178.08 ***	159.52 – 198.81
CHW Event [Yes]	2.95 ***	2.77 – 3.14	1.34 ***	1.27 – 1.40	1.66 ***	1.52 – 1.80	1.98 ***	1.81 – 2.17
time [month]			1.08 ***	1.08 – 1.08	1.16 ***	1.15 – 1.16		
race [American Indian or Alaskan Native]			0.04 ***	0.03 – 0.04			0.03 ***	0.02 – 0.03
race [Asian or Pacific Islander]			0.08 ***	0.08 – 0.09			0.06 ***	0.05 – 0.07
race [Black or African-American]			0.26 ***	0.25 – 0.28			0.17 ***	0.16 – 0.19
race [Other]			0.25 ***	0.24 – 0.26			0.20 ***	0.18 – 0.22
race [Undisclosed]			0.09 ***	0.09 – 0.10			0.08 ***	0.07 – 0.09
ethnicity [Hispanic]			0.18 ***	0.18 – 0.19			0.17 ***	0.16 – 0.19
ethnicity [Undisclosed]			0.08 ***	0.08 – 0.09			0.09 ***	0.08 – 0.10
CHW Event [Yes] × time					0.97 ***	0.96 – 0.98		
CHW Event [Yes] × race [American							1.06	0.91 – 1.22

Indian or Alaskan Native]								
CHW Event [Yes] × race [Asian or Pacific Islander]							1.22 **	1.07 – 1.40
CHW Event [Yes] × race [Black or African-American]							1.61 ***	1.43 – 1.80
CHW Event [Yes] × race [Other]							1.24 ***	1.11 – 1.38
CHW Event [Yes] × race [Undisclosed]							1.08	0.95 – 1.23
CHW Event [Yes] × ethnicity [Hispanic]							0.96	0.88 – 1.05
CHW Event [Yes] × ethnicity [Undisclosed]							0.78 ***	0.70 – 0.86

Random Effects

σ^2	3.11	1.17	2.62	1.35
τ_{00}	0.27 $_{County}$	0.13 $_{County}$	0.21 $_{County}$	0.16 $_{County}$
ICC	0.08	0.10	0.07	0.11
N	99 $_{County}$	99 $_{County}$	99 $_{County}$	99 $_{County}$
Observations	27037	18784	27037	18784
Marginal R^2 / Conditional R^2	0.064 / 0.139	0.670 / 0.704	0.189 / 0.250	0.623 / 0.664

*p<0.05 ** p<0.01 *** p<0.001*