If You Build It, Will They Come? Is Test Site Availability a Root Cause of Geographic Disparities in COVID-19 Testing?

Brian Hendricks, Bradley S. Price, Timothy Dotson, Wes Kimble, Sherri Davis, Maryam Khodaverdi, Adam Halasz, Gordon S. Smith, Sally Hodder

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Authors:

Brian Hendricks[1,2*], Bradley S. Price[2,3], Timothy Dotson[2], Wes Kimble[2], Sherri Davis[2], Maryam Khodaverdi[2], Adam Halasz[4], Gordon S. Smith[1,2], Sally Hodder[2]

Affiliations:

[1] School of Public Health, West Virginia University, Morgantown, WV 26506, USA

[2] West Virginia Clinical and Translational Sciences Institute, Morgantown, WV 26506, USA

[3] John Chambers School of Business, West Virginia University, Morgantown, WV 26506, USA

[4] Department of Mathematics, West Virginia University, Morgantown, WV 26506, USA

***Corresponding Author**

Brian Hendricks, PhD

School of Public Health

West Virginia University

64 Medical Center Dr.

Morgantown, WV 26056

USA

E: bmhendricks@hsc.wvu.edu

Tel: 304-293-5256

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ABSTRACT

Objectives: The purpose of this study was to examine the relationship between test site availability and testing rate within the context of social determinants of health.

Study Design: A retrospective ecological investigation was conducted using statewide COVID-19 testing data between March 2020 and December 2021.

Methods: Ordinary least squares and geographically weighted regression were used to estimate state and zip code level associations between testing rate and testing sites per capita, adjusting for neighbourhood level confounders.

Results: Findings indicate that site availability is positively associated with the zip code level testing rate and that this association is amplified in communities of greater economic deprivation. Additionally, economic deprivation is a key factor for consideration when examining ethnic differences in testing in medically underserved states.

Conclusion: The study findings could be used to guide delivery of testing facilities in resource-constrained states.

Keywords: COVID-19, Test Uptake, Underserved States, Geographically Weighted Regression

INTRODUCTION

The US has faced unprecedented challenges to its public health infrastructure over the last 3 years. The COVID-19 pandemic has caused, and continues to cause, large scale impacts on households, communities and governments [1]. To date, hundreds of millions of people have received COVID-19 testing within the US alone [2]. Modalities and delivery of testing vary between communities, but typically relate to (1) presentation of a symptomatic patient or (2) population-level disease and preventive screening [3]. During the early phase of the pandemic, before COVID-19 vaccines, testing led to the implementation of control measures such as mask wearing and social distancing [4-6]. After rollout of the vaccine, testing reduced by one-third across the US [7]. However, the reduction in testing was short-lived, as utilisation of available testing services increased with the detection and surges in positive cases of the COVID-19 Delta variant in April and August 2021, respectively [8]. The high number of positive cases remained constant through to the end of 2021 for states such as West Virginia, and official reports of the Omicron variant were detected in December 2021 [9].

Testing inequities have received considerable research focus over the last 2 years. Studies highlight disparities in the rate of COVID-19 testing within communities of colour, urban and rural gradients, the level of food insecurity and economic deprivation [10-13]. Given that the objective of many studies is to identify areas of low testing (i.e. prevalence of testing), it's no surprise that the majority of studies focus on future resource allocation as the primary endpoint [14]. Few studies have examined whether the addition of more testing resources (i.e. adding new testing sites) actually results in an increase in the testing rate within underserved communities. Uncertainty regarding the effects of test site availability on testing rate is a critical limitation to the current COVID-19 literature. Successful population-scale testing regimens rely on the use of testing sites, which can vary based upon public trust, and organisational and social factors, which can vary over space and time [15].

West Virginia is an ideal location to explore the impact of test site availability on testing rate within medically underserved communities. Past research in the state has identified disparities in testing and positivity of tests for COVID-19 at the census tract level, with higher testing uptake seen in the Black/African American population, urban residents and within communities that were more food secure [16]. The current study builds upon previous studies by examining whether geographic differences in test sites per capita contribute to disparities in the testing rate among medically underserved communities. Importantly, this research examines how neighbourhood level factors, such as area deprivation and rural minority populations, influence the relationship between testing rate and test sites per capita. Results will provide an understanding of how social determinants of health impact test site utilisation. Additionally, the findings will address the limited research on testing uptake and can be used to optimise delivery of resources to slow the spread of the COVID-19.

METHODS

Data Management

Zip code level testing data were obtained from the West Virginia Department of Health and Human Resources from March 2020 (when the first case of COVID-19 was detected in the state) to December 2021. Data contained unique patient identifiers, polymerase chain reaction (PCR) test results, date test was performed, zip code of testing site and patient zip code of residence. Inconclusive tests were excluded from the analysis. The remaining testing data were aggregated so that each row of data represented a unique person who tested either positive or negative by month and zip code. Patients who were tested multiple times within a month and zip code were regarded as negative if all tests were negative, and positive if at least one test within the month indicated positivity. PCR testing data were joined to an ESRI USA Zip Code Points shapefile containing 2019 estimated population data within zip codes [17]. Testing rate and unique testing sites per 1000 persons were estimated for each zip code using the US census population estimates contained within the ESRI USA Zip codes shapefile. This study was approved by the West Virginia University Institutional Review Board (protocol # 2204554630).

Testing data were linked to five-digit zip code Area Deprivation Index (ADI) state level rankings and 2019 census tract level estimates of Black/African American population percentages. ADI rankings ranged from 1 to 10, with higher scores indicating higher disadvantage for a zip code relative to other zip codes in West Virginia [18]. The percentage of a zip code population identifying as Black/African American was obtained through intersecting the zip code level testing data with 2019 census tract level estimates of Black/African American population percentages [19]. Covariates also included three continuous by continuous interaction terms, as follows: (1) testing sites per 1000 persons by ADI ranking; (2) testing sites per 1000 persons by Black/African American percentage of the population; and (3) Black/African American percentage of the population by ADI ranking. The outcome for this study was the log transformed zip code level testing rate.

Statistical Analyses

Separate multivariable ordinary least squares (OLS) and geographically weighted regression (GWR) analyses were performed for each month from March 2020 to December 2021 (n = 22 months). OLS regression was used to identify statewide estimates, while GWR was incorporated to identify local differences in testing rate by testing sites per capita, and adjusted for the Black/African American percentage of the population and ADI. Mathematical specification for OLS and GWR are presented in equation 1. For GWR, i = 1…..n, γ_i is the model outcome at the i^{th} zip code, β_{i0} is the regression intercept, β_{ik} is the regression coefficient for the k^{th} covariate, x_{jk} is the observed value for the k^{th} covariate, p is the number of regression terms, and ε_i is the random error term for the i^{th} zip code [20].

OLS	$\gamma_i = \beta_0 + \beta_k x_k + \varepsilon_i$
GWR	$\gamma_i = \beta_{i_0} + \sum_{k=1}^{p-1} \beta_{ik} x_{ik} + \varepsilon_i$

Eqn. 1

Importantly, GWR was only conducted for 4 of 22 total months of the study. This was done to limit bias from multiple testing [21], while also highlighting the effects of testing sites per capita on testing rate at key time intervals across the study period. The 4 key months were (1) March 2020 (first COVID-19 case detected in West Virginia); (2) November 2020 (increased COVID-19 testing efforts and resources); (3) August 2021 (COVID-19 Delta variant surge); and (4) December 2021 (first COVID-19 Omicron variant positive patient detected) [22]. The spatial window for GWR analyses was selected using an adaptive bandwidth and cross-validation scores in the "spgwr" R package [23]. Resulting GWR coefficients representing the effect of sites per 1000 persons on the testing rate were mapped at the zip code level. Shading of points was determined based upon the coefficient values as well as their corresponding t-values. t-values were used to determine if the local GWR coefficient was statistically significant at the 0.05 level. This approach aligns with previous research noting the importance of providing t-values side-by-side with local coefficients for proper interpretation of GWR results [24].

Temporal trends were explored between the testing rate and model covariates by month using scatterplots. Scatterplots included y-axes to display variation in OLS coefficient and its corresponding t-value, and month on the x-axes. The extent to which interaction effects influenced first order effects for covariates were visualised by creating categorical 'bins' for zip code level ADI ranking and Black/African American percentage of the population based upon one standard deviation distance from the statewide average for each variable. For example, zip codes with an ADI ranking or Black/African American percentage of the population one standard deviation above the state average were categorised as ‘high’. Alternatively, zip codes with an ADI ranking or Black/African American percentage of the population one standard deviation below the state average were ‘low’. All others were categorised as ‘medium’.

RESULTS

Results from the OLS models are summarised for each month (n = 22) from March 2020 (month 3) to December 2021 (month 24) in Figure 1. The red line is the regression coefficient, the solid blue line is the corresponding t-value, and the dotted blue line is the threshold for statistical significance at the 95% confidence level (CI). The threshold was set at 1.96 given the large (n = 469) degrees of freedom in OLS regression analyses. Months where the solid blue line crosses above or below the dotted blue line, indicate months where there was a statistically significant positive or negative effect, respectively, for that covariate on the testing rate. Overall, testing sites per 1000 persons and Black/African American percentage of the population have statistically positive effects on the testing rate across all months in the study. In contrast, ADI state level ranking has a statistically significant negative effect on testing across all months. Interpretation of these results should be done with caution given the statistically significant interaction effects in the OLS models. ADI ranking had a statistically significant positive interaction effect on the relationship between testing sites per 1000 persons and testing rate for all months (i.e. as ADI state ranking increased, the positive effect that the number of testing sites per 1000 has on the testing rate increases). However, Black/African American percentage of the population had a statistically significant negative interaction effect on the relationship between test sites per 1000 persons and the testing rates for all months, with the exception of months 10–14 (i.e. as the Black/African American percentage of the population increased, the positive affect of testing sites per capita on testing rate decreased). This result is complicated, as there is a statistically significant negative interaction effect for Black/African American percentage of the population on the relationship between ADI and the testing rate (i.e. as ADI increases, the positive effect that Black/African American percentage of the population has on testing is offset).

Mapped results from the GWR analyses for the 4 key months are shown in Figure 2. Zip codes where test sites per 1000 persons had no significant local effect on testing rate are shown as grey dots. Zip codes where test sites per 1000 persons had a statistically significant local effect are displayed using a blue to red gradient, where lower effects are indicated in blue and higher effects are in red. It is important to note that any zip code with blue or red shading showed a statistically significant positive effect between number of testing sites and testing rate. The blue to red gradient is used to display the extent of the significant effect over time. Spatial trends within these four months suggest that the effect of sites per 1000 persons on the testing rate was highest in the northern and north-eastern regions of West Virginia, particularly during August and December 2021 when new COVID-19 variants were detected or surging.

DISCUSSION

This study provides an empirical foundation to investigate the effect of test site availability on testing rate for COVID-19. Importantly, the impact of higher availability of testing sites on the testing rate was examined from a health disparities perspective during 4 key months of the pandemic for West Virginia. Findings indicated clear geographical differences in the extent to which test site availability impacts testing rate across the state as a whole and within communities at the zip code level. Furthermore, results suggest that the positive effects of site availability on the testing rate are influenced by neighbourhood level social determinants of health. This is a critical finding within the context of the four key time intervals of the pandemic (March 2020, November 2020, August 2021 and December 2021) as it provides an opportunity to understand the impact of public health services during surges in cases and when new variants are detected.

Previous research in West Virginia has identified census tracts with higher Black/African American percentage of the population as a significant predictor for lower COVID-19 testing [16]. The current study results from March 2020 and December 2021 are in line with this conclusion, showing that the impact for sites per capita on testing is lower among communities with a higher Black/African American percentage of the population. However, caution must be taken in the interpretation of these results, as this was not true for all key time intervals examined. No significant relationship was detected when extensive testing resources were available across the state. In November 2020, access to testing increased rapidly due to state level mandates from the West Virginia Office of Governor [25]. In August 2021, a surge in testing was associated with detection of the SARS-CoV-2 Delta variant, which was more transmissible and virulent than previous SARS-CoV-2 variants [26]. As such, a possible explanation is that during times of low testing, overall test uptake was lower among communities that also happened to have a higher Black/African American percentage of the population; thus, this does not infer that testing is lowest among Black/African American communities. Results from this study also showed a positive linear relationship between Black/African American percentage of the population and the testing rate, indicating an increase in testing among communities with a higher Black/African American percentage of the population. Therefore, this study suggests that the negative interaction effect identified between Black/African American percentage of the population and test sites per capita could be a result of the fact that the communities themselves had a lower testing rate. This potential theory was tested (results not shown) and it was found that the relationship between Black/African American percentage of the population and testing rate was modified by community deprivation. This is an important result as the negative linear relationship between ADI and testing rate mitigated the positive effect that Black/African American percentage of the population had on the testing rate.

A previous study also examined the impact of ADI on disparities in COVID-19 testing and positivity within West Virginia but found no significant effect on testing or positivity [16]. Upon closer examination, the incidence rate ratio reported for ADI in this previous study was 1.31 (95% CI 0.99 to 1.75), indicating that for some census tracts, ADI had a weak negative effect and a strong positive effect on testing. In West Virginia, there are 484 census tracts and 851 zip codes (including PO Box addresses) [27,28]. One possible explanation for the differences in these results is that the use of the more detailed zip code level data reduced variability in ADI, which was estimated as the mean of census block group data in the previous study. The significance of ADI as a predictor of COVID-19 risk has been established in many studies across the US [29-31]. The current study examined impact of ADI on the use of testing resources, as opposed to COVID-19 risk, and found that testing sites per capita had a greater impact in communities of greater disadvantage. This is an important finding as it informs decision-makers to direct limited resources to areas where they may have the highest impact for disease surveillance and control. Future studies should aim to understand how other social determinants of health impact utilisation of testing resources for COVID-19 and other infectious diseases.

Some limitations of the currently study should be noted. Perhaps most importantly, the trends identified are related to PCR testing data and do not include rapid antigen testing. This is a potentially important distinction, as higher or differing availability of rapid antigen results could bias the testing rate observed. Additionally, the case definition for a positive COVID-19 test in the current study is prone to potential misclassification if samples were improperly handled or if patients were tested too early. That said, PCR testing data have been demonstrated to be more sensitive than rapid antigen testing [32] and samples, with few exceptions, were delivered to the laboratories within 24 hours of the time the swab was obtained.

Conclusions

This study addresses gaps in the COVID-19 literature surrounding the impact of test site availability on population-level testing rates and explores how these relationships change when considering social determinants of health. The finding that higher test site availability increases testing uptake for areas of higher community deprivation could inform targeted testing regimens. Results provide critical information to inform future dissemination of testing resources within medically underserved and underrepresented rural groups. The current findings regarding higher Black/African American percentage of the population and lower uptake of testing reflect the challenges of delivering tests within underrepresented rural groups. This study found that it was not the Black/African American populations themselves that had lower testing, but that other neighbourhood level factors, such as ADI, were partially responsible for the disparities observed.

Further research on health services delivery and use for testing for COVID-19 and other infectious diseases during the pandemic are warranted. For example, qualitative studies are ideally suited to better capture the lived experiences of community groups [33-35] and may determine other factors involved in the trends identified among communities with a higher Black/African American percentage of the population, particularly when factoring in community deprivation. The effects of test sites per capita on testing rate differed dramatically across West Virginia. Overall, higher impacts were noted for northern and north-eastern West Virginia, particularly after detection of new SARS-CoV-2 variants. Lastly, the consistent positive relationship for interaction between ADI and sites per capita on testing is encouraging, particularly given that previous research in West Virginia identified a positive, although not statistically significant, relationship between disadvantaged communities and SARS-CoV-2 testing rate [16]. Taken together, although within different temporal aspects, this suggest that disadvantaged communities take full advantage of testing resources when available, leading to higher testing rates.

Author statements

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Ethical approval

This study was approved by the West Virginia University Institutional Review Board (protocol # 2204554630).

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Competing interests

The authors have no conflicts to declare.

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Figure 1. Monthly change in statewide (ordinary least squares [OLS]) regression coefficients and their corresponding t-values for each covariate. Months on the y-axis start at 3 and end at 24 corresponding to March 2020 until December 2021.

The red line is the regression coefficient, the solid blue line is the corresponding t-value, and the dotted blue line is the threshold for statistical significance at the 95% confidence level. ADI, area deprivation index; % Black/AA, Black/African American percentage of the population.

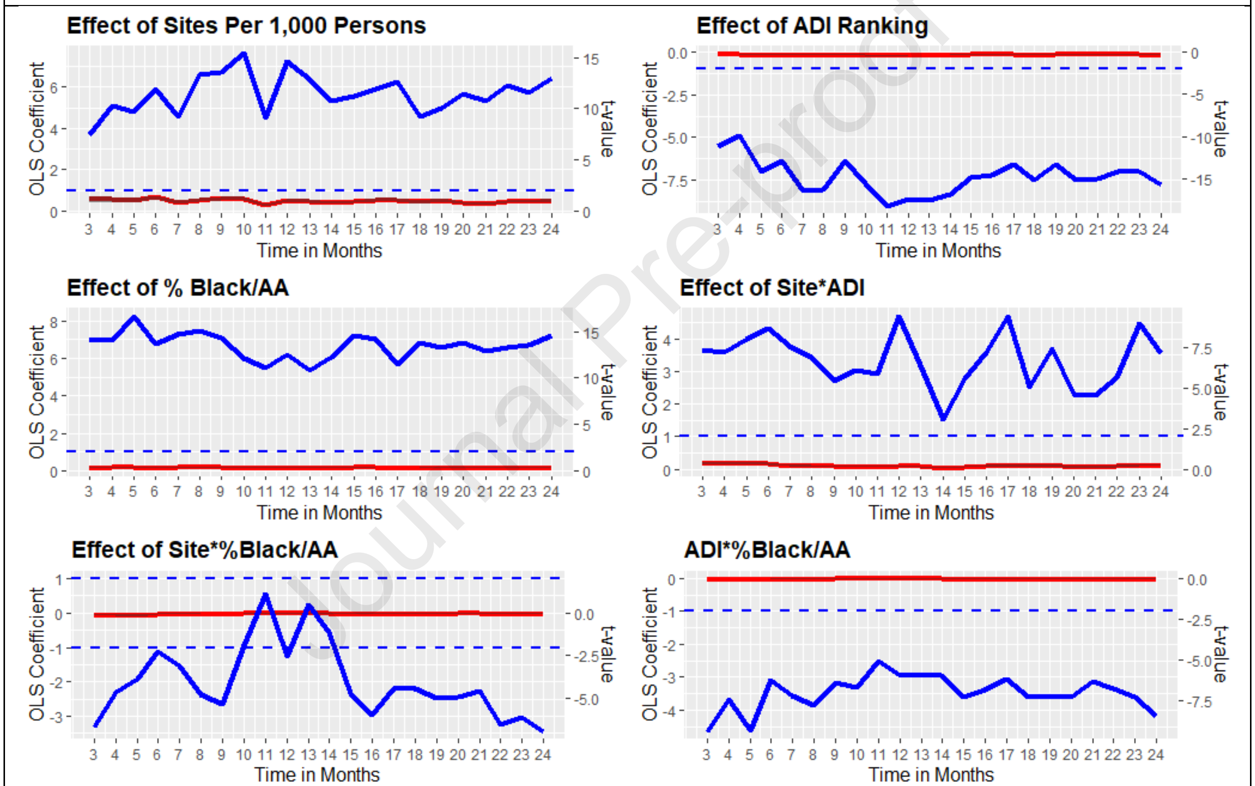

Figure 2. Local coefficients from geographically weighted regressions (GWRs) examining the effect of testing sites per 1000 persons on the testing rate by zip code for March 2020, November 2020, August 2021 and December 2021.

Zip codes with grey dots indicate no statistically significant effect of test sites per 1000 persons on testing rate. Zip codes where test sites per 1000 persons had a statistically significant local effect are displayed using a blue to red gradient, where lower effects are indicated in blue and higher effects are in red. It is important to note that any zip code with blue or red shading did observe a statistically significant positive effect between number of testing sites and testing rate. The blue to red gradient is used to merely display the extent of the significant effect over time.